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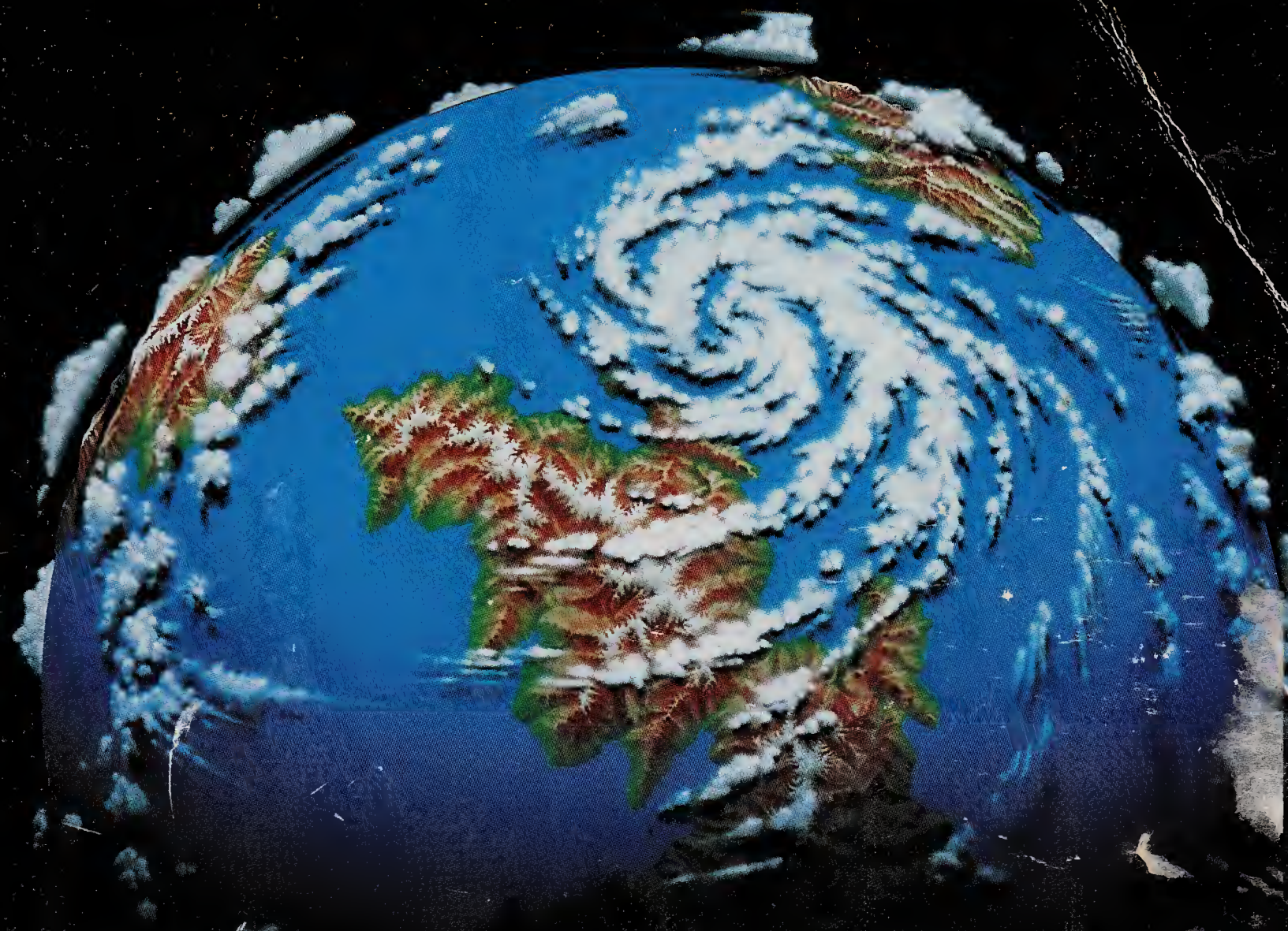

SimEarth

THE OFFICIAL STRATEGY GUIDE

Rusel DeMaria

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SimEarth: The Official Strategy Guide

Rusel DeMaria

(with a Preface by James Lovelock)

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Writing this book was a project that absorbed me for months, in sickness and in health... literally. I am glad to be finished with it, but in a way I never will be. Writing this book has opened doors in my mind that will remain open to new facts and ideas.

Despite the self-absorption I experienced while researching and writing this book, I have a virtual army of people to thank, all of whom made substantial contributions to the eventual completion of this project.

Zach and Ocean were indispensable in so many ways. Ocean was responsible for some of the early insights I had in SimEarth, including some basic fundamentals of the Civilization Model. He also contributed much of the original artwork in this book, including all the 3D renders, and helped process all the rest. And the many Zachs kept us all laughing.

Will Wright was a paragon of patience and ever willing to provide me with information and just good discussion of the Gaia model and of SimEarth in general.

Fred Haslam, like Will, was always ready to help me with the details of the model.

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In memoriam: Muttly the dog

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Preface

by James Lovelock

One of the delights of being an independent scientist living on my wits and not on a weekly or monthly pay check, is the possibility of becoming a small part of a project like SimEarth. Few of the scientists who sell their labour to universities or institutions would dare take on so unconventional a task.

My first intimation of SimEarth came through the receipt of a review copy of SimCity from Maxis. As an active working scientist I don't have too much time for playing computer games; also I spend a fair amount of time making models of what I think is the real world. This activity is in itself an ultimate form of game playing, the perfect and endless solitaire. But I soon found that SimCity was much more than an arcade game, it was more like a professional model and was credible as a map of the real world, and I enjoyed playing it. Later I received a letter from Will Wright of Maxis describing their new project SimEarth, or as it was then called 'Gaia'. In the letter Will Wright asked if I would help with their development of the game. I accepted immediately for I could think of no more intriguing a task than to help develop a game model of Gaia. Especially if it was made by the same firm who had done so well with SimCity. Will Wright then sent a disk with the current development stage of the game and a Macintosh on which to run it. I don't know how much help I was to Maxis, but I do know how much the game fascinated me and my grandchildren. From the beginning we were amazed at the degree of detail possible with just a personal computer. Professional science modelers tend to sneer at anything smaller than a $30,000 work station; yet their models are often no more than one dimensional maps, and if two dimensional, limited to a single variable like temperature only. There are 3D global models with detail down to 100 kilometer squares, but these need super computers.

One of the many things that impressed me about both SimEarth and SimCity was the quality of the manuals. The bright intelligent computer people who write manuals even for systems costing over $100,000 more often than not are incoherent and illiterate. Their writing is not just painful

to read but wholly misleading. This is puzzling, for English is also a language used for communication and programs. Not much use being fluent in assembly if you can't explain what you have done. In addition to having a fine and clear manual, SimEarth has transcended the tradition of illiteracy that mars computer products by having this book, written by Rusel DeMaria, as a guide for novitiates. He clearly and concisely explains SimEarth and its background and writes with an imaginative style that will keep you reading it to the end.

In the brief and turbulent history of computer science it is recognised that many of the great advances in graphic displays came from arcade game programs. Natural selection among games soon led to the survival of the fastest, the brightest and the best. I do believe that the scientists involved with the serious problems of the global and local environment will find inspiration from the brilliant graphics programming techniques developed by Maxis. Meanwhile, to get the feel of it they could not do better than to play SimEarth.

Playing games is more than just fun, it is the natural and proper way of education. Watch a kitten playing with a ball and see how it fine tunes the program it will soon be using to pounce upon a mouse or catch a bird in flight. SimEarth also is both a game and a model of the Earth. It shares a lot in common with the professional models that meteorologists use, that run on super computers to forecast the next day's weather, or the climate of the next century. You could, at vast cost, rent time on one of these super models to play games. You could ask for the model to be programmed to answer questions like, what if a hyper hurricane formed in the mid Atlantic? What would the winds be like when it hit land in New England? Or ask what would be the climate of the 21st century if Saddam Hussein had released 20 million tons of CFC's into the atmosphere instead of setting fire to Kuwait's oil fields?

SimEarth is in a way descended from a primitive model called Daisyworld that I made in 1981 to show that the Gaia theory was not just a flight of fancy. Daisyworld is the working hypothesis that offers an explanation of how the world's climate had kept constant and comfortable, in spite of the Sun having increased its heat output by 25% over the time life has existed on Earth.

Scientific theories about the Earth, the Solar System or the Universe usually have a hard time with traditional

scientists, particularly during the first twenty or thirty years after their introduction. Plate tectonics took forty years to become accepted as fact, and it looks as if Gaia, now only twenty years old as a theory, will take about as long. There is nothing wrong about this. The investment in current conventional wisdom is vast and naturally scientists view with dismay the prospect of having to reorient their thinking to a new view of the world, and to have to rewrite their text books. Naturally many have responded by fierce attacks, by attempting to prevent the publication of papers on Gaia, and by trying to prevent funds being granted for research on Gaia. This is unfortunate, but in practice there are always those with enough courage to do the work anyway.

Gaia is a hard science theory about the evolution of the Earth and the life upon it. In no way is it contradictory to Darwin; it extends Darwinism to include the evolution of the rocks, the atmosphere and the oceans. Gaia theory sees the evolution of the material world and the evolution of the organisms as a tightly coupled process. Changes in the organisms always affect the environment and vice versa. The pre-Gaia conventional wisdom saw life and the environment as either entirely separate or only loosely coupled. Life simply adapted to the environment, and the environment was a given state of geology. It will be some time before Gaia is accepted as fact. Meanwhile, look on it as a theory up for trial by experimental test and by the gathering of evidence from the real world. Ignore those who try to demolish Gaia by sophistry, calling it untestable, or who say it has all been said before.

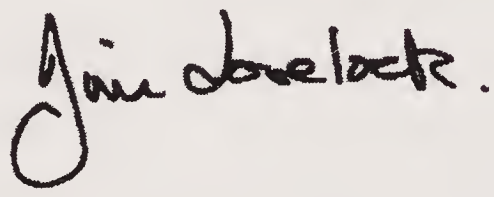
You can test the theory yourself by playing the Daisyworld game in SimEarth and observing how the evolution of the daisies and the evolution of the global climate are coupled together. You can see that turning up or turning down the Sun's heat only slightly changes the temperature of this imaginary world.

The Daisyworld model expresses the essence of Gaia. This model can be made so that climate control is exerted by plants that vary the level of CO2 rather than the color of daisies. Or it can be made to show the regulation of oxygen at 21 per cent by competition between species of trees using fire as a weapon.

For most of you SimEarth will be no more and no less than a splendid game. But I have hope that it might develop

into something more, a personal model that might become a guide for living right with the world. A way of testing for ourselves the long term consequences of different ways of living.

A model not much more complex than SimEarth could have been sufficient to predict that the fires in Kuwait would have only local, not global, consequences. To look further ahead, it would be wonderful if the initial conditions of a personal model descended from SimEarth were updated continuously by satellite. Such a personal model would make us all aware of the real world as it is. We might all then see the vast fires that mark the destruction of the forests throughout the humid tropics. We might see the great algal blooms in the oceans and watch the clouds form above them. But we could also still play games with it and in so doing learn to live better with our planet.



Coombe Mill
2 May 1991

Foreword

by Will Wright
with
Fred Haslam

Many people have the impression that computer programs are always predictable and fully understood by the designer. Those of us who design software know that this is not always the case. As computer games and simulations like SimEarth evolve toward a higher level of complexity, they begin to take on a life of their own. Understanding the interactions of 10 variables can be tricky, 100 variables quite a bit more difficult... But when you have thousands of them you just sit back and watch. While designing SimEarth, Fred Haslam and I spent quite a bit of time just doing that—observing the behavior of the model we had created and then attempting to coax it closer to reality, bit by bit.

What really impresses me about Rusel DeMaria is his ability to observe the processes occurring in SimEarth and then come to understand the underlying reasons for those processes. In many instances this is an understanding that cannot be gleaned from examination of the underlying algorithms, though quite a bit of that also went into this book.

While reading the drafts of *SimEarth: The Official Strategy Guide*, and over the course of many discussions with Rusel, I have come to learn a great deal more about SimEarth than I had known even after programming and testing the simulation. I believe that the clear introduction to SimEarth and Earth science provided in these pages will open both the game and the subject of our planet to a wider audience. And I know this will help anyone using SimEarth to gain a clearer understanding of it, its limitations, its abilities, and also the real world it represents.

Will Wright
Fred Haslam
May 7, 1991
Orinda, California

Introduction

When I first heard about SimEarth, it was just an idea that the folks at Maxis were kicking around. After all, how do you follow a program like SimCity? What was the next logical step? At the time, the program's working title was Gaia, and that was the first time I heard about the Gaia principal which formed the basis of the SimEarth project.

At the time, I was Senior Editor of PCGames Magazine, and was always on the lookout for programs of exceptional interest. With the success of SimCity, I had confidence that Maxis would produce a winner, but I had no idea how they would make a game out of a planetary simulation. The issues were just too vast. They dwarfed the issues involved in SimCity.

Jeff Braun at Maxis explained the concepts that formed the basis of the Gaia project and told me that, where SimCity had worked around one mathematical model, Gaia would be based on five separate, but interacting models. I was incredulous, but also excited at the prospects.

So I kept in contact with Maxis, checking in on the program in its various stages of development. You might say that SimEarth became a pet project of mine as well, even though I had nothing to do with its development.

When I became the editor of the Secrets of the Games series of books for Prima Publishing, one of the first book projects I wanted to write was SimEarth. Of course, being a good businessman, my publisher asked me whether I thought the product was going to sell well (meaning could we make money on a book about it). This was still months before the program was even ready for beta testing, and it was far from finished. I told Ben I couldn't guarantee anything, but it was a book I really had to do. Once he understood the nature of the program and its significance, he agreed.

Now it's easy to look at SimEarth and realize what a wonderful product resulted from those original ideas. And it is with great pleasure that I have written this book. The pleasure is not only in the opportunity to work with SimEarth and its designers, Will Wright and Fred Haslam, but also the great wonder I've experienced while learning about our Earth and how it evolved. When I began the project, my lack of knowledge was prodigious. It is now a miniscule portion less

so, but the new understandings I have gained have felt like a feast to a hungry man or a first hint of light to the blind.

Another great pleasure has been the opportunity to learn about James Lovelock's Gaia hypothesis. In reading his wonderful books and in communicating with Dr. Lovelock, I've been amazed at how his vision has changed my thinking about this planet. Perhaps beginning with the first Earth images received from outer space, our appreciation for the uniqueness of this planet has continued to grow with each passing decade. The Gaia hypothesis helps us see this warm, blue sphere not as a rock which happens to support life in the middle of the forbidding void of space, but as an organism that has successfully sustained its own state of aliveness for billions of years. Are we part of the evolution of a super organism? Will we be the beings that help that organism reproduce itself in space and throughout the galaxy? These are some of the questions I've considered since encountering Dr. Lovelock's remarkable theory. My view of the world is forever changed.

Mixed in with the pleasure and the wonder, however, is a dark cloud. In the course of my research I've become even more aware than ever how Man has mismanaged this planetary resource, and how we show no signs of taking the necessary action to reverse the destruction we've set in motion.

For that reason, this book is composed of essentially three kinds of information. The main body is, of course, all about SimEarth. I've attempted to provide all the information you'll need to play the game effectively, including lots of secrets and undocumented information to give the most complete look at SimEarth possible. I hope you'll find that this book fulfills all your SimEarth needs.

The second kind of information I've included in this book is about Earth science. Because SimEarth is based on real scientific principles, it presents an opportunity to learn much more about our home planet. However, in many ways SimEarth makes compromises in order to work on a personal computer. I had an expression whenever I would encounter such limitations—F.O.A.F. (Fits On A Floppy). So I've attempted to provide more insight throughout this book on the real fundamentals of our planet's origins and working systems. Not all the information about Earth science is necessarily the truth. Nobody really knows what the truth is,

and scientists tend to differ in their viewpoints. I've tried to stick pretty close to conventional wisdom most of the time, though I admit once again to monumental ignorance, and have relied on a relatively small number of resources to get the facts included in this volume.

The third kind of information is the most disturbing. I think of this as the modern ecological information section. Like much of the Earth science, you'll find this information in sidebars throughout the book. In these sections, I've attempted to distill the information from several excellent sources to provide an idea of the situation we face on Earth today. These subjects include such well-publicized issues as global warming and the greenhouse effect, the growing ozone hole in the sky, deforestation in the Amazon and elsewhere, and other issues that may receive less publicity, but are no less compelling.

In some cases, I may repeat myself. If so, it is because the subject matter is critical to our survival. Even if some of the so-called crises turn out to be paper tigers, there is more than enough to be concerned about. It is my hope that by bringing these issues to your attention, we'll all be able to remember our priorities and perhaps take action to stop our destructive behaviors and find ways to live in harmony with our world.

Rusel DeMaria
May 14, 1991
Kula, Hawaii

About This Book

This book is divided into four main sections: Part I: The Tutorial, Part II: The Reference, and Part III: The Simulations. Part IV contains some special information about SimEarth, including a troubleshooting guide and a glossary.

The Tutorial is designed to give you some real experience with SimEarth. It is somewhat challenging for beginners, but it is arranged so that you can try parts of it more than once, until you get it the way you want it. That's because SimEarth is not like a game where the same thing happens every time you play. Each time you take control of a planet, it seems to act just a little differently. I've tried to help you understand how to interpret planetary behavior and to give you experience with a wide variety of the tools available in this complex product. By the time you've finished the Tutorial section, you'll understand SimEarth well enough to try just about any experiment you want.

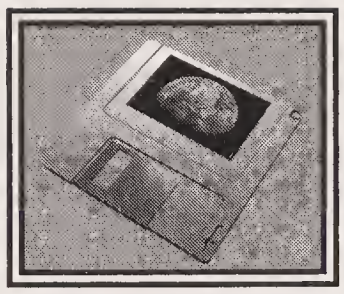
In the Reference section, I've detailed all the main parts of SimEarth in much the same way as they did in the manual that accompanies the product. However, there is a lot of information in my Reference that is not in the manual. You'll learn many secrets as well as how the model works. In addition, there are numerous sidebars on Earth science and on ecological situations that I hope you'll enjoy. So reading the Reference should add a lot to your understanding of this product.

In the Simulations section, I give you some concrete suggestions for enjoying the various games included in SimEarth. In particular I look at some challenging ways to play with Aquarium, Stag Nation, Modern Earth, the Mars and Venus scenarios, and Daisyworld. There are lots of ways to play these simulations and I've tried to offer a few good ideas. By no means does that prevent you from coming up with many others.

HOW TO READ THIS BOOK

IMPORTANT: PLEASE READ THIS SECTION

This book is not always linear. For instance, you may be reading along in the Tutorial section or the Reference and suddenly come across a sidebar about ice ages or deforestation, or something related to the current narrative, but not part of it.



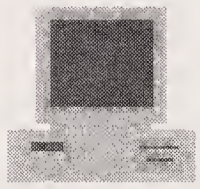
Each sidebar is marked with a recognizable icon.

Stands for a sidebar about how SimEarth works.

Stands for a sidebar about Earth science.

Stands for a sidebar about a modern ecological situation.

Because there is more than one version of SimEarth, we've come up with a way to let you know when we're talking about your version.



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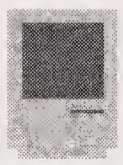


Stands for a special note or information for users of the Macintosh version of SimEarth.

I hope you'll see this as more than just a book about a computer game. Just as SimEarth itself is more than a game, I want this book to entertain and teach at the same time. If I'm successful, you'll come away knowing a lot more about SimEarth, and perhaps interested enough to seek out additional reading on geoscience and modern ecology. If so, I'll consider my efforts to have been well worthwhile.

Our theories of the eternal are as valuable as those a chick might form before it has broken through its shell to the outside world.

—Gautama the Buddha

Gaia

Standing on the Earth at any given place, you might suppose that the planet is a ball of rock, or dirt, or water, or even concrete and glass. Or you might imagine it as a spinning rock in space that somehow supports a thin film of living matter. Standing at any given location, you might not suppose that the Earth is, itself, an organism.

Suppose you could fly up into space and see the planet from a few thousand miles up. You would see a sphere of brilliant blue covered over much of its surface with swirling white. In some places you would see the brown and green surface of the continents, but most of the surface, in fact two-thirds of it, would be blue, and the thin film of atmosphere surrounding the planet would be clear.

From that perspective in space, the Earth is unique. No other planet looks like ours, and none offers the unique qualities that make it a suitable home for life as we know it. Some planets are barren and lack atmosphere, water, or any other ingredient that might support life. Others are gas giants swirling with poisonous windstorms many times larger than the Earth itself. Still others are frozen worlds covered with methane ice, only a few degrees above Absolute Zero.

Given this perspective, it is easy to see our Earth as unique. It is the only one that has an atmosphere so improbable that it must be the result of some active force. If

nothing were to sustain it, our atmosphere with its particular concentrations of nitrogen, oxygen, carbon dioxide, methane, and other elements simply could not exist for long. Oxygen is too volatile and would combine with other elements very quickly if it weren't being replaced. This is true of methane as well. An Earth-like planet, without any other mechanism to contradict its basic chemistry, would end up with an atmosphere composed largely of carbon dioxide. Our nearest planetary neighbors, Mars and Venus, demonstrate this quite effectively.

Scientists refer to the situation as the Goldilocks principle. That's because Venus is too hot, Mars is too cold, and Earth is juuust right! Yes, only Earth shows any signs of life.

So the question to ask is, "Why does Earth occupy this unique position in the solar system?" It is the answer to that question that led James Lovelock to come up with the Gaia hypothesis.

If the Gaia hypothesis is correct, then Gaia is a living organism, perhaps not exactly like a fish or a cockroach or a man, but an organism still. If Gaia were to tell a story, maybe it would be something like this:

First there was bright, blasting energy... subatomic chaos, spreading in all directions at once. There was no identity, no self, not even matter. Just energy in motion. A dream with no dreamer.

Time passed, though there was no reference for it. In that time, the energy slowed. It cooled. It solidified into the simplest of matter, the hydrogen atom. Everywhere there was hydrogen, as particles slowed and aggregated and became.

More time saw these atoms themselves aggregate, and somehow, as they grouped together and pressures built, great fusion reactors were created. These were the first stars. Still, there was no identity or awareness.

Much more time passed. Many billions of Earth years, though there was no Earth yet. There were stars everywhere, becoming, shining, and dying in great explosions that sent their matter and energy spreading into new places.

One such star exploded and sent energy and matter flying across the universe. Some of the matter passed through a dense gas cloud, perhaps a cloud that was about ready to condense and form its own star. Within this gas cloud, this nebula, a star ignited, but still there was no sense

of waking from the dream. Not yet. Perhaps I stirred in my sleep. No more.

Around the new star was matter that escaped the gravity and heat of the fusion reaction. That matter was colliding, crashing, smashing, and forming new matter. In time, it formed satellites of the new star—planets.

Now my sleep grew restless. It was on the third planet from the star that I felt the dream begin to fade and the dawn of my day begin. The elements were there and though I could not direct them consciously, I felt it when they became life. Still, I was not completely awake.

When did I awaken? Slowly, as the new Earth cooled and the new life spread. The planet, left alone, would have slid into a steady state—a dead state. Life could not follow the natural chemical process. My appearance came subtly as life itself maintained its environment to suit itself. No longer at the mercy of entropy, life altered and maintained a world suitable to sustain it.

Life evolved and the face of the world changed. It grew in complexity and motion. Emerging from the seas of its birth it spread over the land, and my presence was felt in the way the world was altered and kept in its improbable stability.

It was much later—billions of years after I appeared—that the consciousness and unique society of Man developed. This was a new sphere, the sphere of mind, of stored knowledge, and of foresight. And yet I, Gaia, still existed, still maintained. I have never ceased.

This new consciousness could not comprehend me in its own terms. I am not a consciousness like a mind. I am the force of life who maintains. I am the interaction of creatures and chemicals that keeps the temperature of air and ocean comfortable, that keeps the salinity of the seas, the oxygen levels, the nitrogen in the soil, the water on the land and so much more. It all happens at once. I don't focus on one thing and then another as Man does. I am all of it, best understood as a complex system of feedback, positive and negative, that, through all its changes maintains conditions for life.

How fragile am I? I have survived billions of years. During that time, the Sun has grown steadily hotter, yet the temperatures I maintain have varied little. I have survived the impacts of giant meteors which might have killed much of the life on the surface of the planet. I have seen pollution events that poisoned billions of creatures, and yet I survived and thrived.

When Man appeared, a new sphere joined the six ancient spheres: fire (the Sun), lithosphere (earth),

atmosphere (air), hydrosphere (water), cryosphere (ice), and the biosphere (life). The new sphere, the noosphere, is the world of mind, of consciousness. It is part of me and I am not separate. I am the force of all life.

How will the noosphere affect me? Some say it is undoing itself, acting contrary to my own maintenance. Some say it will kill me, but it will not. It may kill itself, but I will remain.

Some say that consciousness is my means of reproduction, that I will use the conscious creatures to spread myself and the essence of my seven spheres beyond the planet Earth and into space.

Those that say these things are, themselves, members of the conscious class of creatures. They know little of me, though they study my parts and look at me in isolated places. They may attribute thoughts and intentions to me, but my actions are not subject to such simple explanations.

Meanwhile, time and life.

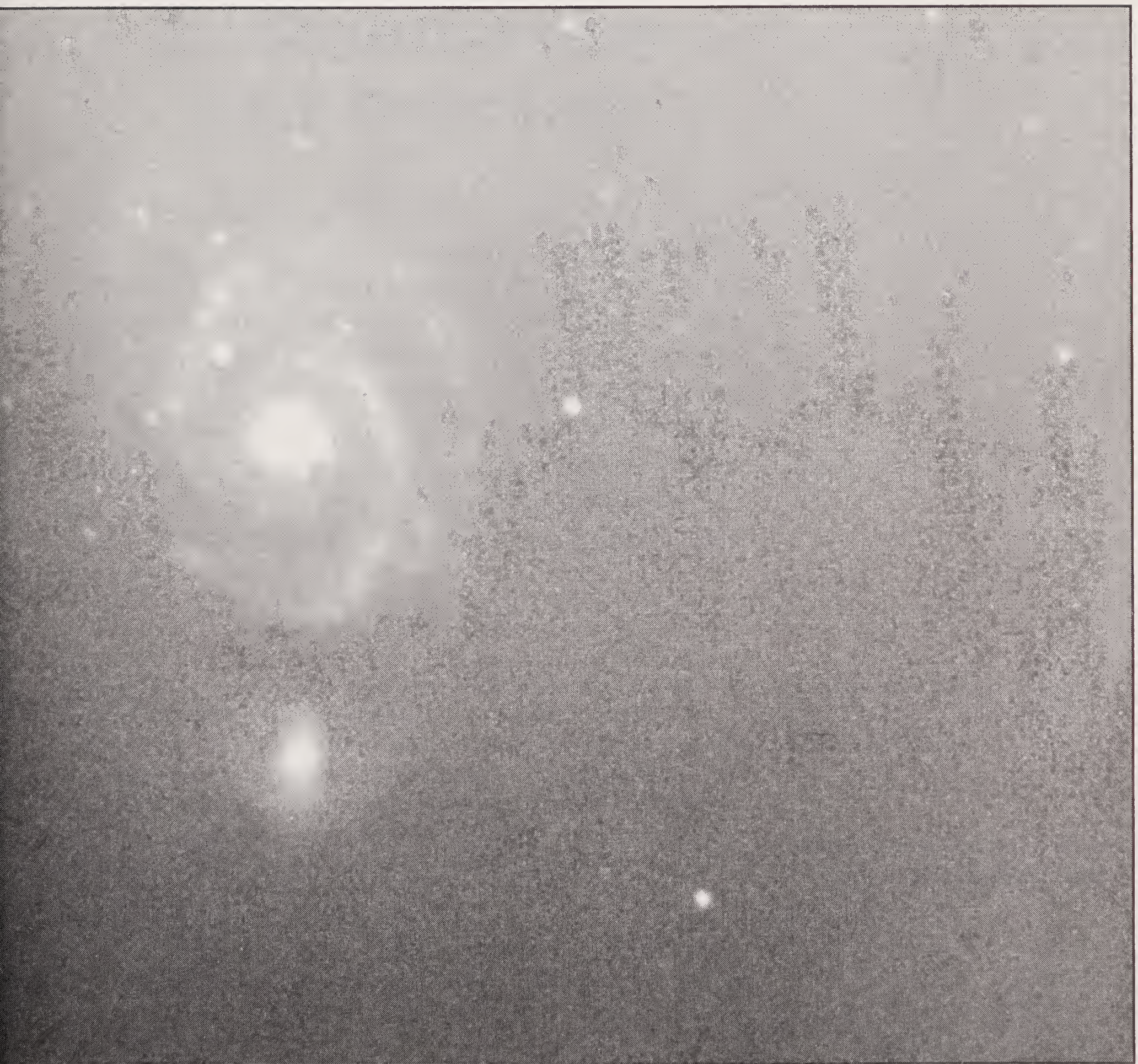
Of course this character, Gaia, is just a fiction. The story is being told, certainly, but not in such words and concepts. It is being discovered in the record of rocks, in the frozen gases trapped in ancient ice, in the remote and hidden places of the Earth, and in the exploration of space and what we learn from it. Gaia is no more a creature with human-like consciousness than a flower is. And yet a flower may exhibit intelligence enough to know when to open and when to close, to know what scent to give off to attract an insect to pollinate it, or even to know what shape to take to imitate its symbiotic pollinators. The flower isn't conscious in human terms, but it is an organism capable of acting appropriately to maintain its own survival.

In some way, the totality of life on Earth may be an organism in the same way. It knows how to regulate and maintain, even, perhaps, actively to create the conditions it needs to continue. If this is so, then Gaia is truly an organism, not a giant rock in space. And we are part of the whole Gaia, not something above and separate from it. We inherited this world, but it was prepared and maintained for us for billions of years. Our ancestors only set foot on the planet a few paltry millions of years ago. Something preceeded us. Something made us possible. We need not deify it, but we should do our best to understand it and to cooperate with it.

Part I

SimEarth—The Fast Path: A G.O.D.S. Field Guide

"We aren't gods, we just make 'em."
—G.O.D.S. motto (as quoted to the author by Will Wright)



On the previous pages: A spiral nebula. Seeds of more worlds?

1 / Orientation and Practice

This tutorial is a fast track into SimEarth—a handy travel guide of sorts. By the time you've followed the steps in this tutorial, you should be completely comfortable with SimEarth, ready to strike out in daring new adventures of your own. We've chosen to get right into the action here (with only a few preambles) so you can get the experience of the product. We'll explain things as we go along. Don't worry if you think this product is just too complex and too big to comprehend. That's what this chapter is for. Just sit back, boot up, and have fun!

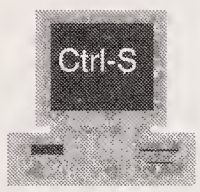
HOW TO USE THE TUTORIAL

You'll find various kinds of information in the pages that follow. Much of the information will explain or further clarify the action taking place on your screen. Some of it adds information from current scientific or environmental opinion to give you some additional perspective. However, whenever you actually need to perform an action, instructions are numbered and presented in bold face. For instance:

1. **Open the Edit window.**

Notice that sometimes icons will appear to the side of the step. This is to indicate that there are keyboard shortcuts for the action in the current step.

Represents a Macintosh keyboard shortcut.



Represents an IBM PC compatible keyboard shortcut.

Pausing and Saving

As you follow the tutorial, there will be times when there is a lot to read and events are happening very quickly on your screen. Get used to using the Pause mode whenever you need to. Don't let the simulation run as you read, or you may get lost. Whenever possible, we will suggest a time to pause, but there will be other times when you'll need to pause even if we don't suggest it.

You'll save your planet under different file names several times during the course of this tutorial. There's a reason to save. SimEarth doesn't always do the same thing every time. Also, it takes some practice to balance some of the powerful forces you'll contend with. You may not get the results you want the first time or every time. That's when you'll be able to go back to the most recently saved version and repeat the steps until you understand them better.

Finally, the tutorial is divided into several major sections. If you want, you can take a break between sections. It doesn't have to be performed in one sitting. Most of all, the tutorial is for fun. We hope you'll have a lot of fun playing with this simulation, and that you'll learn a lot, too.

PLANETARY MANAGEMENT 101

A NEW JOB

You play the part of a new Planetary Manager, just out of training for the galactic conglomerate called Gaia Ontological Development Systems (G.O.D.S.). You're given the job of promoting first life, then civilization, and finally, star travel on a new planet. But you're a hotshot PM, and you have decided that you'll help things along ahead of the recommended G.O.D.S. schedule.

You'll use the standard G.O.D.S. toolkit. It's called the Earth Simulation Module. Earth was an ancient planet;

some say the original birthplace of our species. We call the Earth Simulation Module, *SimEarth* for short.

Of course, because you are new to the job, the G.O.D.S. management has given you a fairly lenient amount of energy units you can expend. These units will replenish over time, but you can't exceed your limit. That's no problem, though. You've studied hard for this moment, and you're determined not to screw it up. But before you get started, how about a little refresher course?

The Dawn of Understanding

At first sight, the job of planetary management in SimEarth may seem complicated beyond belief. After all, how many of us have really thought what we would do if we had godlike powers over our world? As you look over the many menus, windows, and palette icons, you may experience a sense of confusion. What do I do next? What am I trying to accomplish? Why, I don't even remember my G.O.D.S. training...

That's part of the beauty of this program. Even though there is a goal, in SimEarth the journey is truly the reward. It's not so much getting there (wherever you choose to get), but how you get there that is most satisfying.

One of the first things to realize is that SimEarth is like a big laboratory. You can carry out all kinds of experiments; let your imagination reign. Concentrate on little things like creating a few mountain ranges and continental shelves, or take charge of the big picture and see what happens to civilization if the Earth's axis suddenly shifts five degrees.

Perhaps the most important commands in this game are Save Planet and Save As. Using these commands you can, in essence, freeze the simulation at any point. From that point, you can try many different techniques and strategies, always returning to the saved game to try other ideas.

Basic Formations
What You Need to Know

We assume that you already know how to use your pointing device of choice (preferably a mouse), so we won't go into clicks, double-clicks, dragging, and the like. Also, we assume that you know how to select from menus and work with the various windows and graphs.

For more information about the menus, windows, and palette icons, see also the SimEarth Reference later in this book.

Version Differences

We recognize that there have been some schisms among our G.O.D.S. technical support teams, and that, in consequence, not all Planetary Managers have been supplied with absolutely identical equipment. Although the versions are very similar, we will point out differences as we encounter them in the instructions that follow. For a complete keyboard shortcut reference, look at the back page of the manual addendum that came with your version of the SimEarth module.

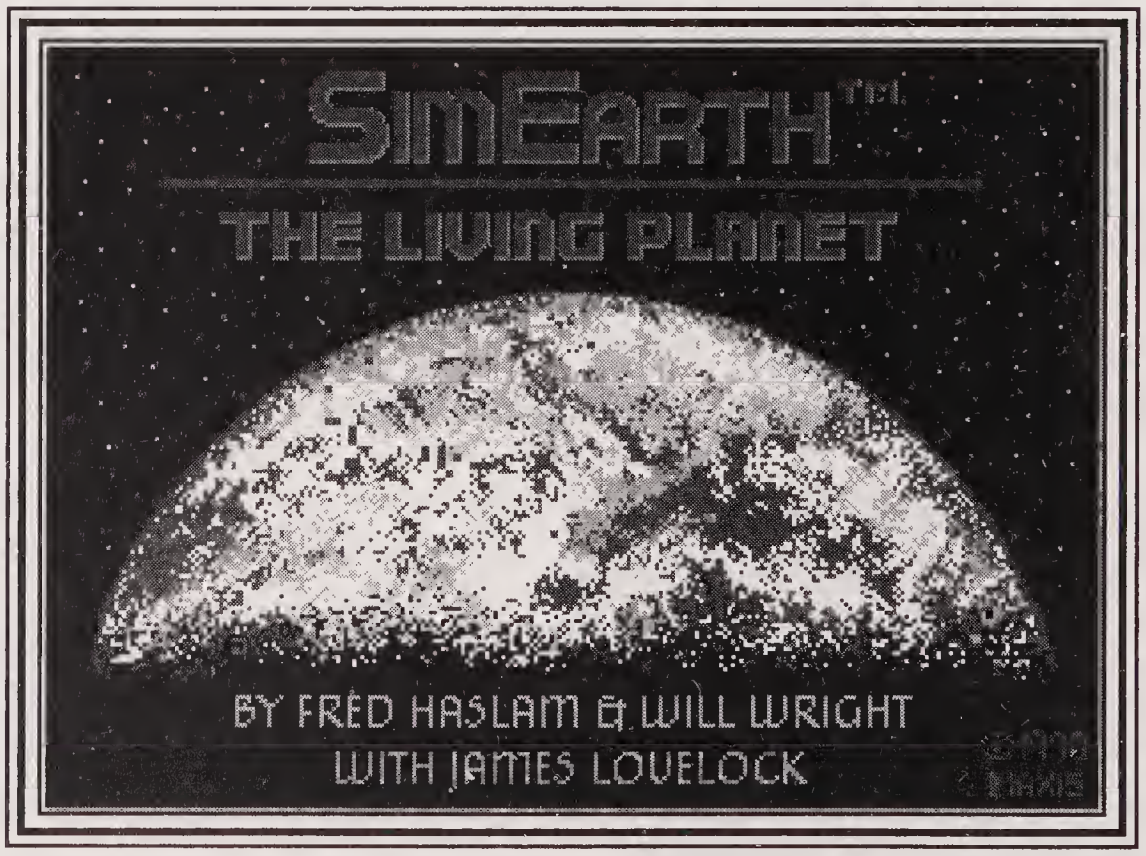
THE PRACTICE RANGE
GETTING FAMILIAR WITH THE BASIC TOOLS

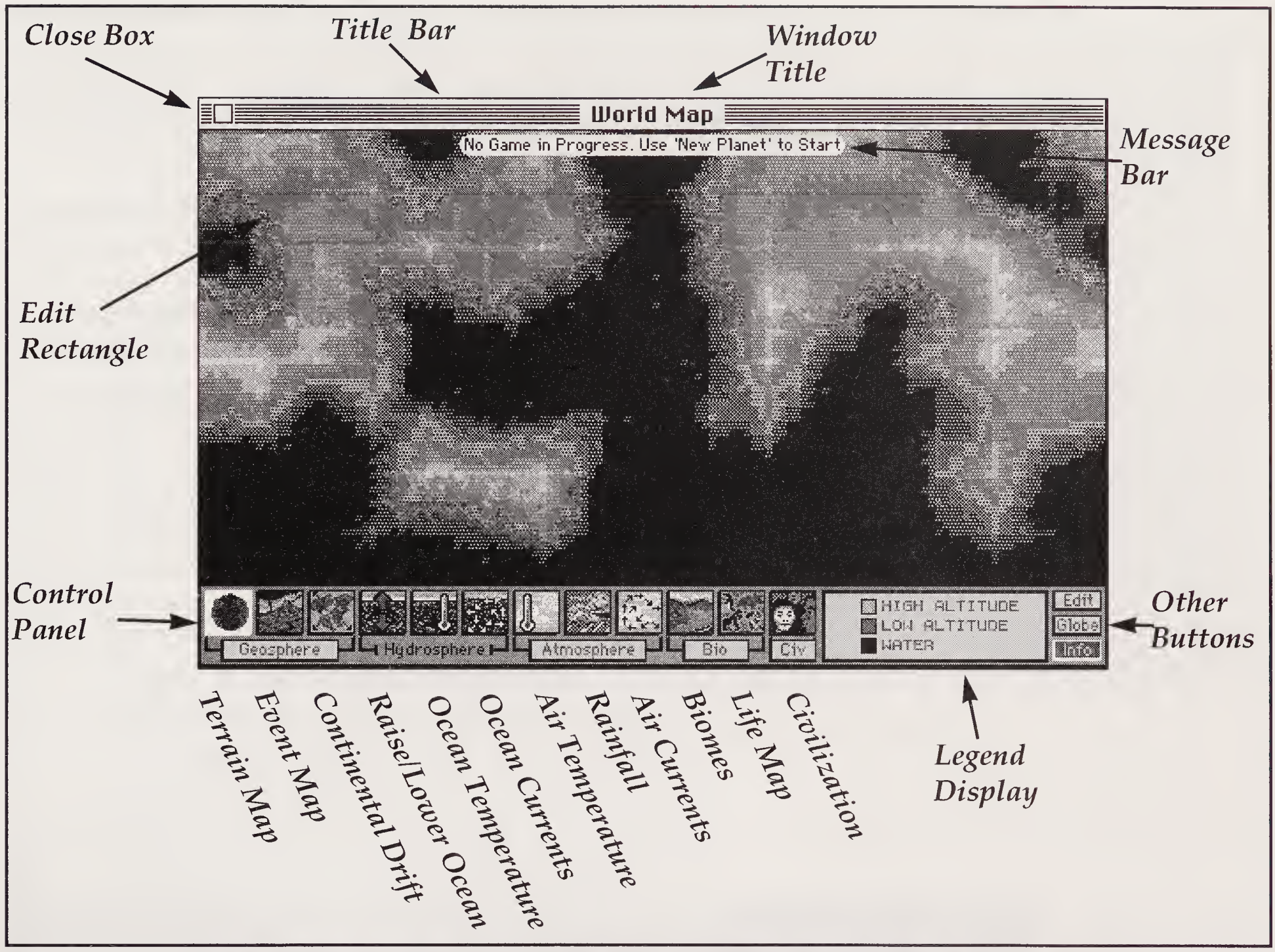
Time: 10 Minutes
Current Goals: Learn to manipulate some windows and tools.

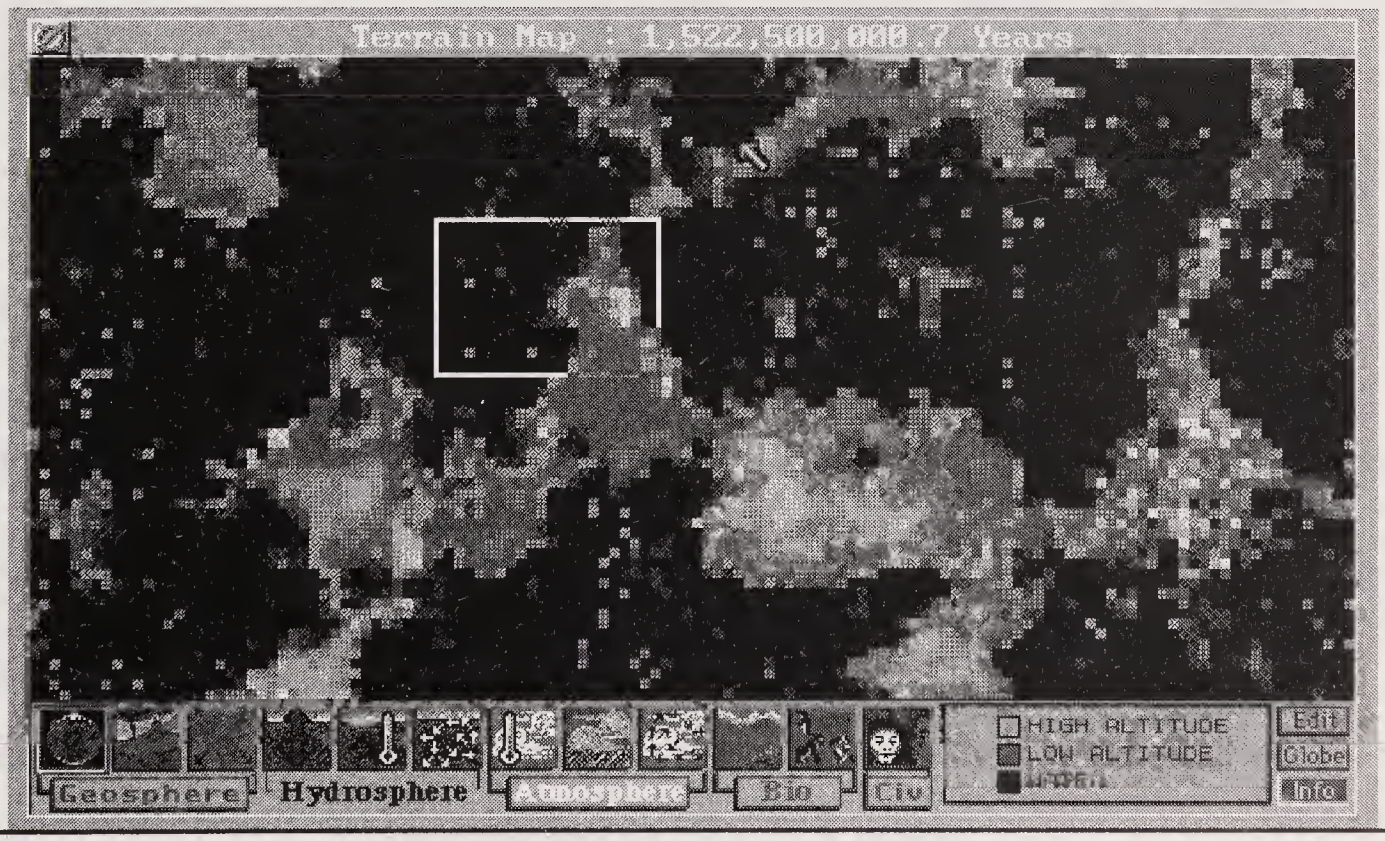
The first thing to do is start the program. If you don't know how, check the manual addendum that came with your SimEarth module.

1. Start SimEarth.

On the Macintosh, double-click the SimEarth icon. On IBM PC compatibles, type *Simearth* in the appropriate directory.







The IBM Map window is almost identical to the Macintosh Map window.

Once the program begins, you should see the Map window.

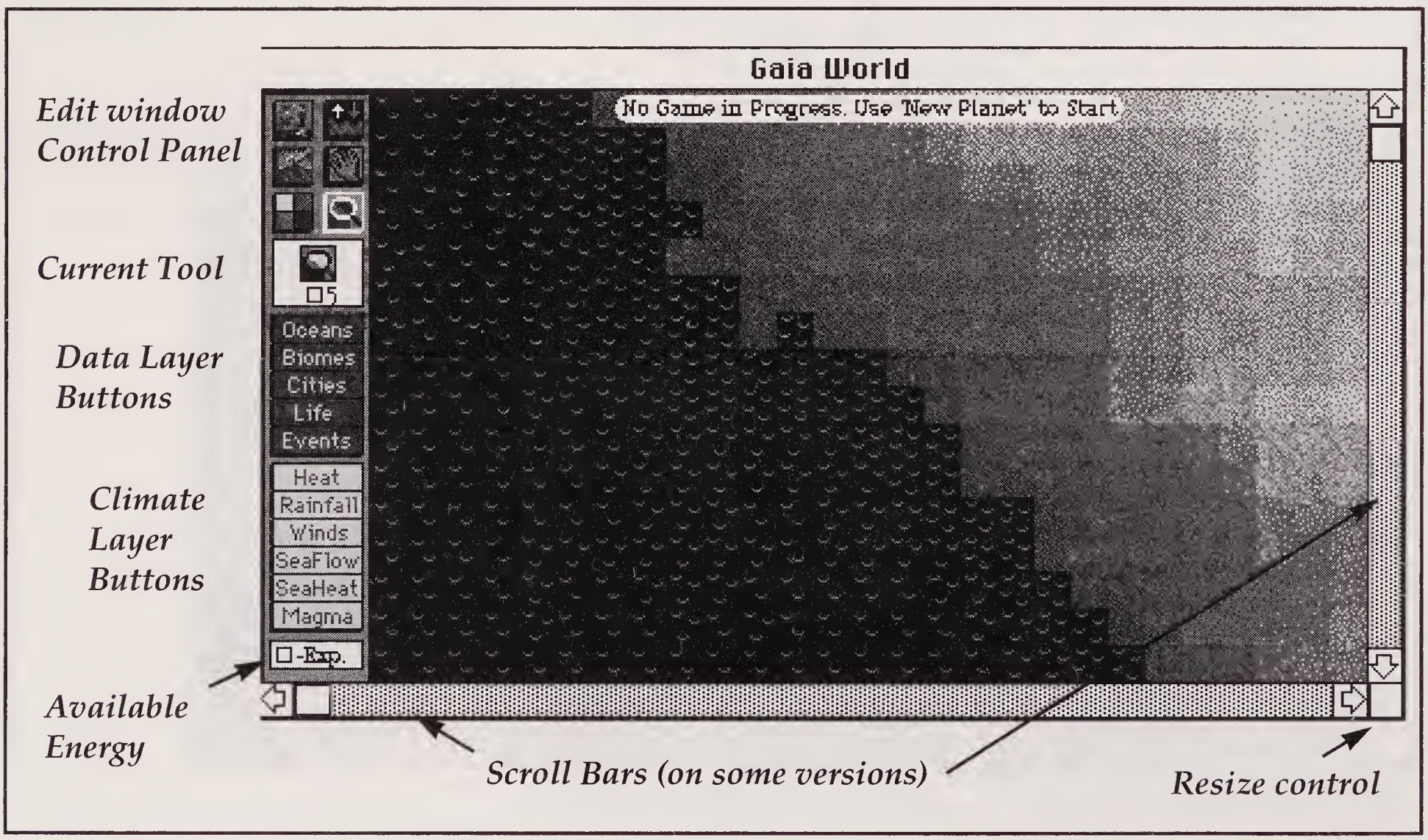
Note: If you have previously played with your module and saved Options and Windows, your screen may show some additional windows. For now, close all but the Map window. Click in the Close Box of any open windows or graphs. The Close Box is always in the upper left corner of the window.

OK. You got a map. That's fine, but don't just sit there and admire the Map. Let's get to work!

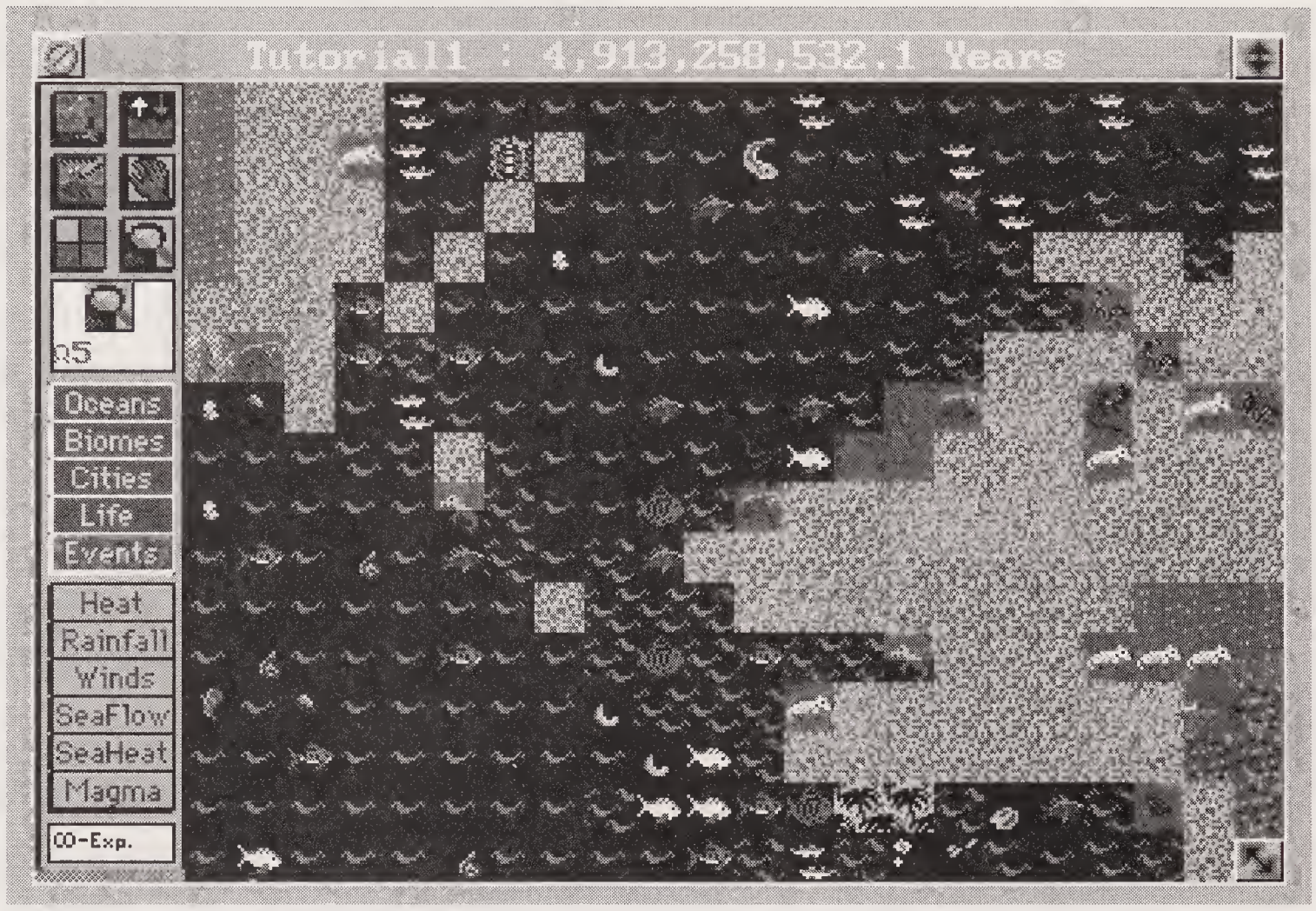
2. Open the Edit window by clicking on the Edit button on the Map window or by selecting Edit from the Windows menu.

Notice that the Edit window is the front window now. That means it is also the active window.

3. Click and drag on the Title Bar of the Edit window and move it into a position on the screen that blocks the least part of the Map window.



The IBM Edit window has no scroll bars. Move the cursor to the edge of the box to move the view. Both windows have Close boxes and Zoom boxes (to make the window full screen size). Controls are all the same.



Edit Windows for Mac (previous page) and IBM (above).

If you are playing on a small monitor, you may not be able to move the Edit window completely off the Map window. If so, move the Edit window to one side, putting part of it off the screen, and move the Map window to the opposite side so you can see at least part of each window.

4. **Now click once in the Map window, bringing it to the front and activating it.**

You'll see a rectangular outline on the map.

5. **Click within the rectangular outline and, still holding the mouse down, drag it around on the map.**

Notice that the view in the Edit window also moves. The Edit window is, in fact, like a real window peeking into the larger world represented in the Map window. The area it

shows is the area bounded by the rectangular outline in the Map window.

6. **Select an area that shows both land and ocean. Then click in the Edit window to activate and bring that window to the front.**

Let's take this opportunity to release any pent-up aggressions. That way we'll be really relaxed when we start our job as new Planetary Manager.

On the left edge of the Edit window you'll see six icons and several command buttons. The command buttons let you decide what you want to see in the Edit window (oceans, biomes, cities, etc.), turning them on or off by clicking on them.

Now look at the icons. The second one down on the left has a picture of a volcano. This is the Event Trigger icon. (We at G.O.D.S. like to think of it affectionately as the "disaster button.")

7. **Click on the Event Trigger icon and hold the mouse to display the list of options available.**

On some versions of SimEarth, the option palette will close if you release the mouse at this point. On others it remains open. Follow the next two steps if your version is of the first type. Otherwise, simply click on the Meteor option and proceed to Step 10.

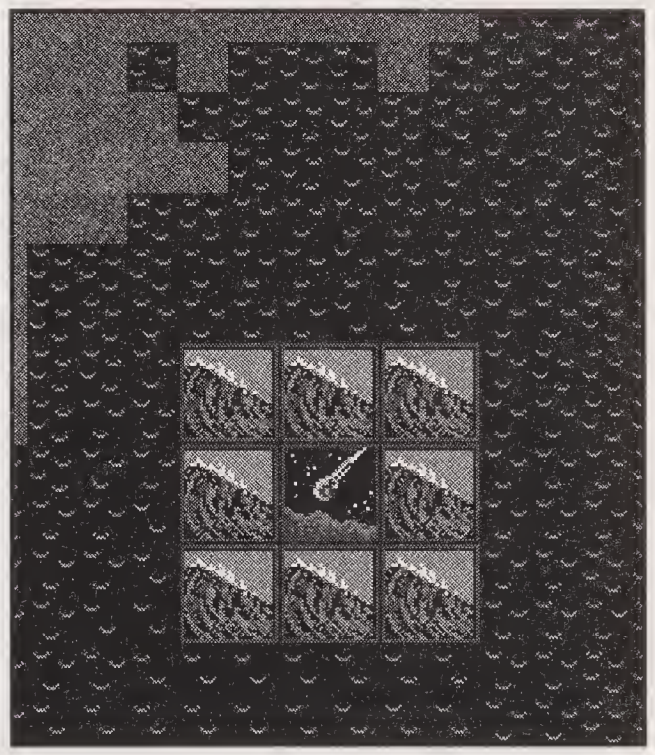
8. **Drag the mouse to the right until the cursor is over the word Hurricane and then drag down until the word Meteor is highlighted.**

9. **Release the mouse button.**

There is a single icon just below the group that contains the Event Trigger icon. That single icon shows the Current Tool. In this case, it should show a small graphic of a meteor striking the surface. That's how you

know what will happen if you click the mouse anywhere in the Edit window display area. Let's do it!

10. Find a place completely in the ocean and click once.



There you go. Your first meteor. Look at the splash it kicks up! Tidal waves in all directions. OK. Now let's do something more interesting.

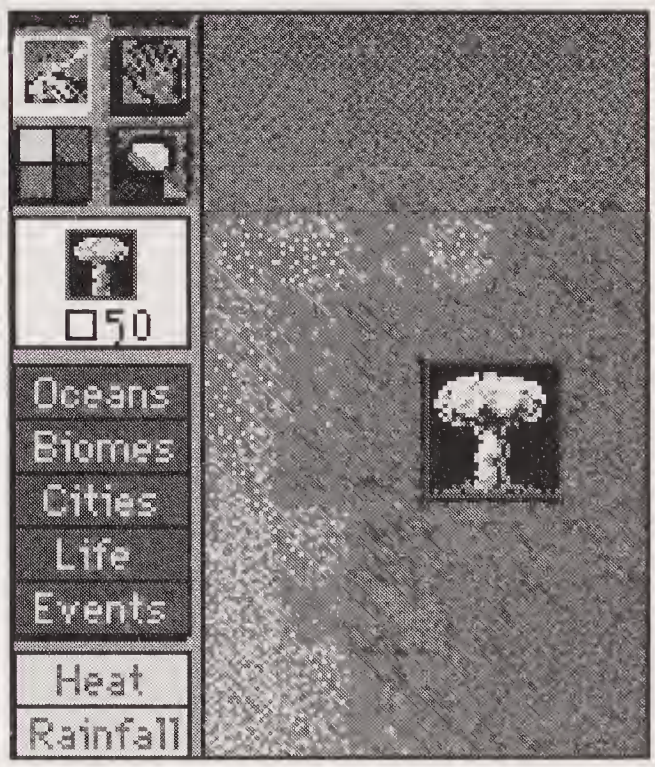
11. Click once on top of a land area.

Look at the hole you made! And look up in the Map window. That hole shows up there, too.

OK. Enough meteors.

12. Return to the Event Trigger icon and this time choose an Atomic Test.

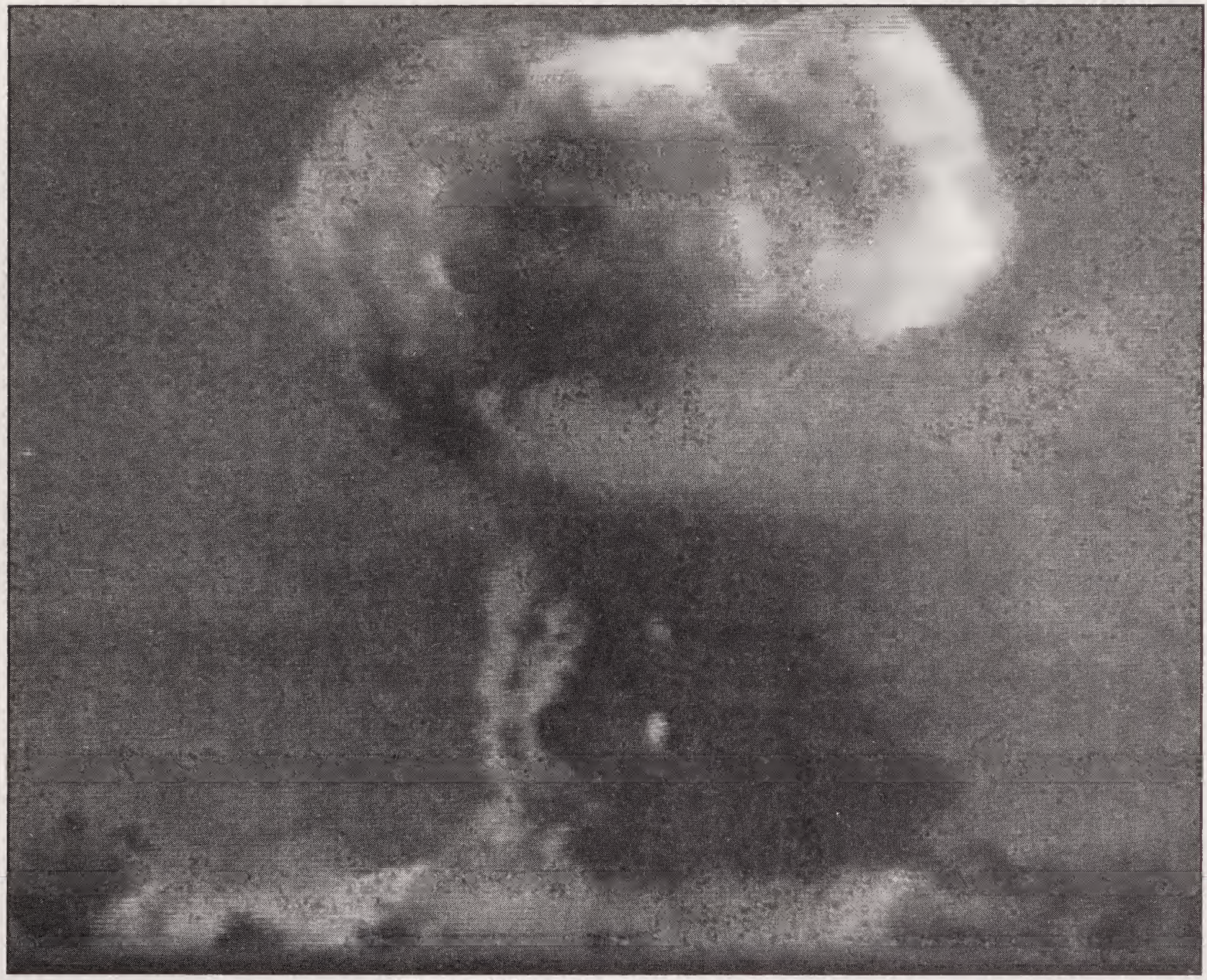
We all know the destructive power of atomic bombs. Why not try one out here? Oh, it's OK. This is just the practice planet. You haven't really started your job yet.



13. Go ahead, drop the bomb!

Not so impressive, is it? At least not after the power of a meteor. But it does leave that radioactive residue for a while. Anyway, you can try some other disasters, like hurricanes, earthquakes, volcanoes, and so forth. Get it all out of your system, because you are about to become the custodian of Gaia, and the keeper of life. Except for the Atomic Test, there will be plenty of events happening all by themselves.

Because you aren't yet managing a real planet, some events may not do anything while others may act strangely. Don't worry at this point. Nothing you do now is of any real importance. Remember, it's just practice.



The real thing is more impressive.

One button to try is the GLOBE button at the bottom right of the Map window. This changes the flat map into a spinning globe.

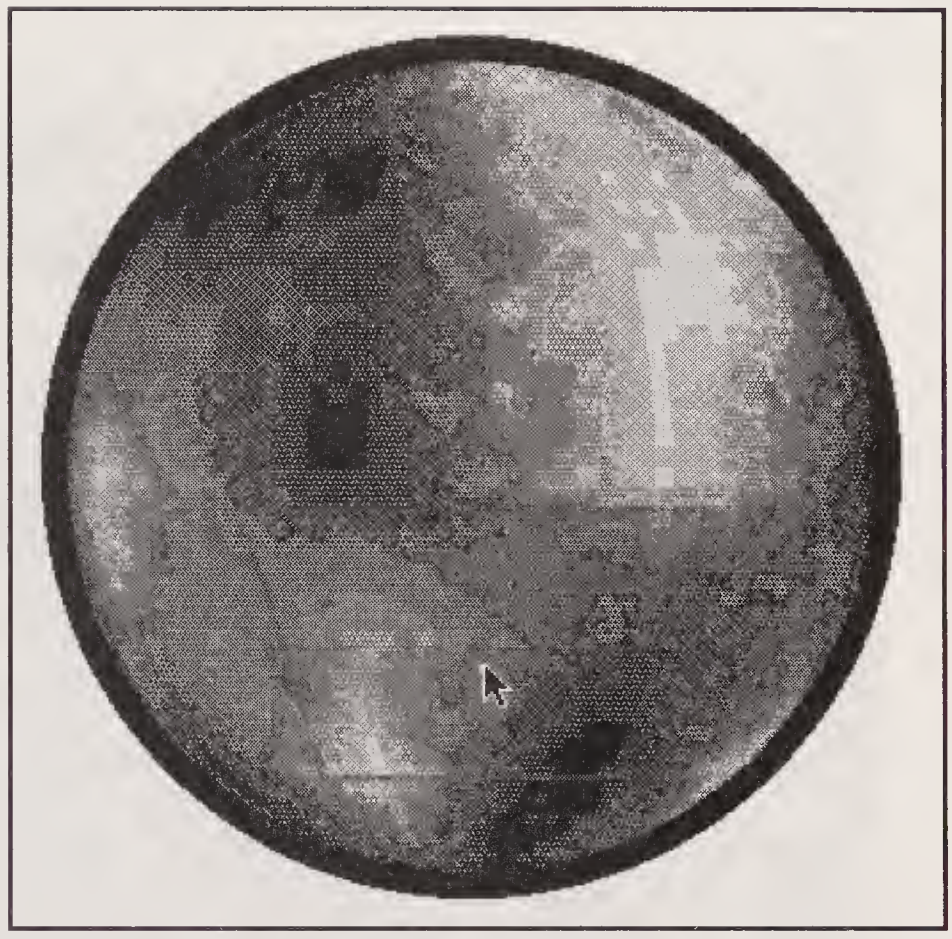
14. **Click once on the GLOBE button.**

15. **To stop the globe, click anywhere in the Edit Rectangle (actually an Edit Trapezoid now).**

16. **To see what the interior of your planet looks like, double-click**

anywhere on the globe outside the Edit Trapezoid. Then click again to see the normal view of the globe.

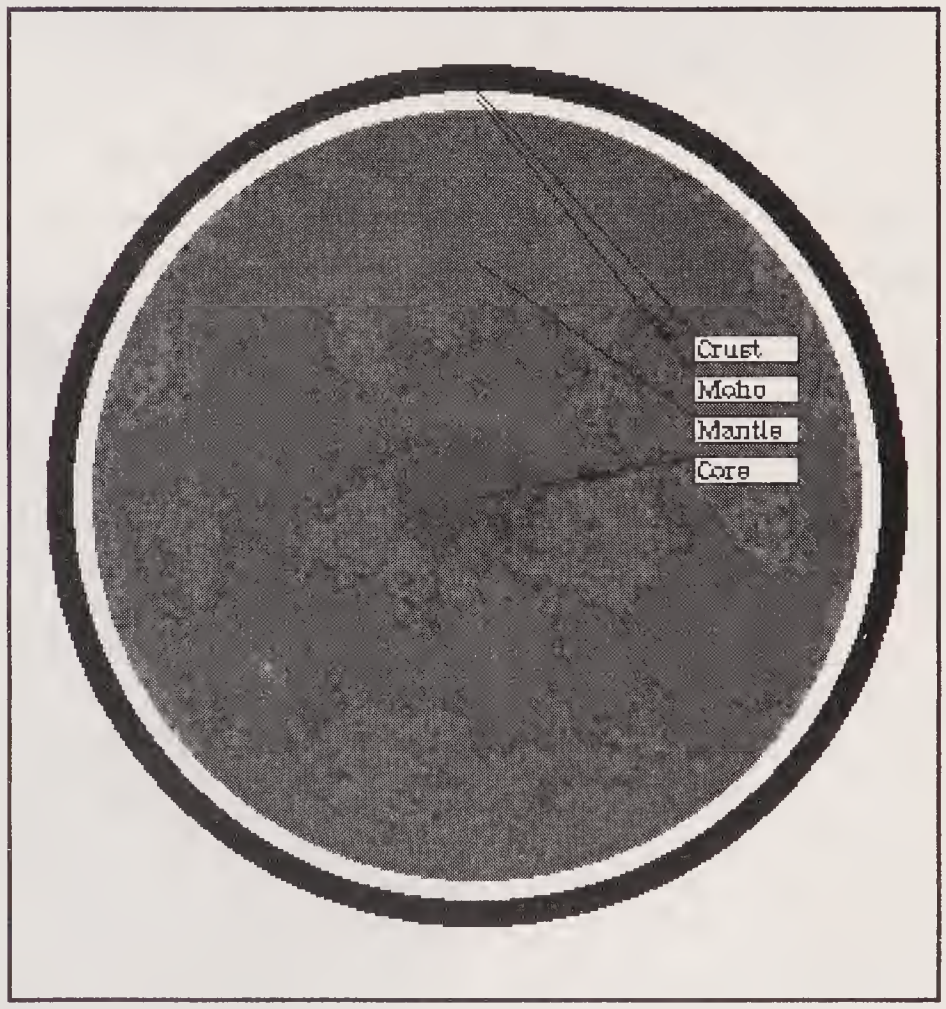
We have found some variation when viewing the interior of the Globe. However, basically it will show the core and crustal layer of the world. Also, on PC compatibles, you can open the Map window control panel by clicking on the icon in the lower right corner.



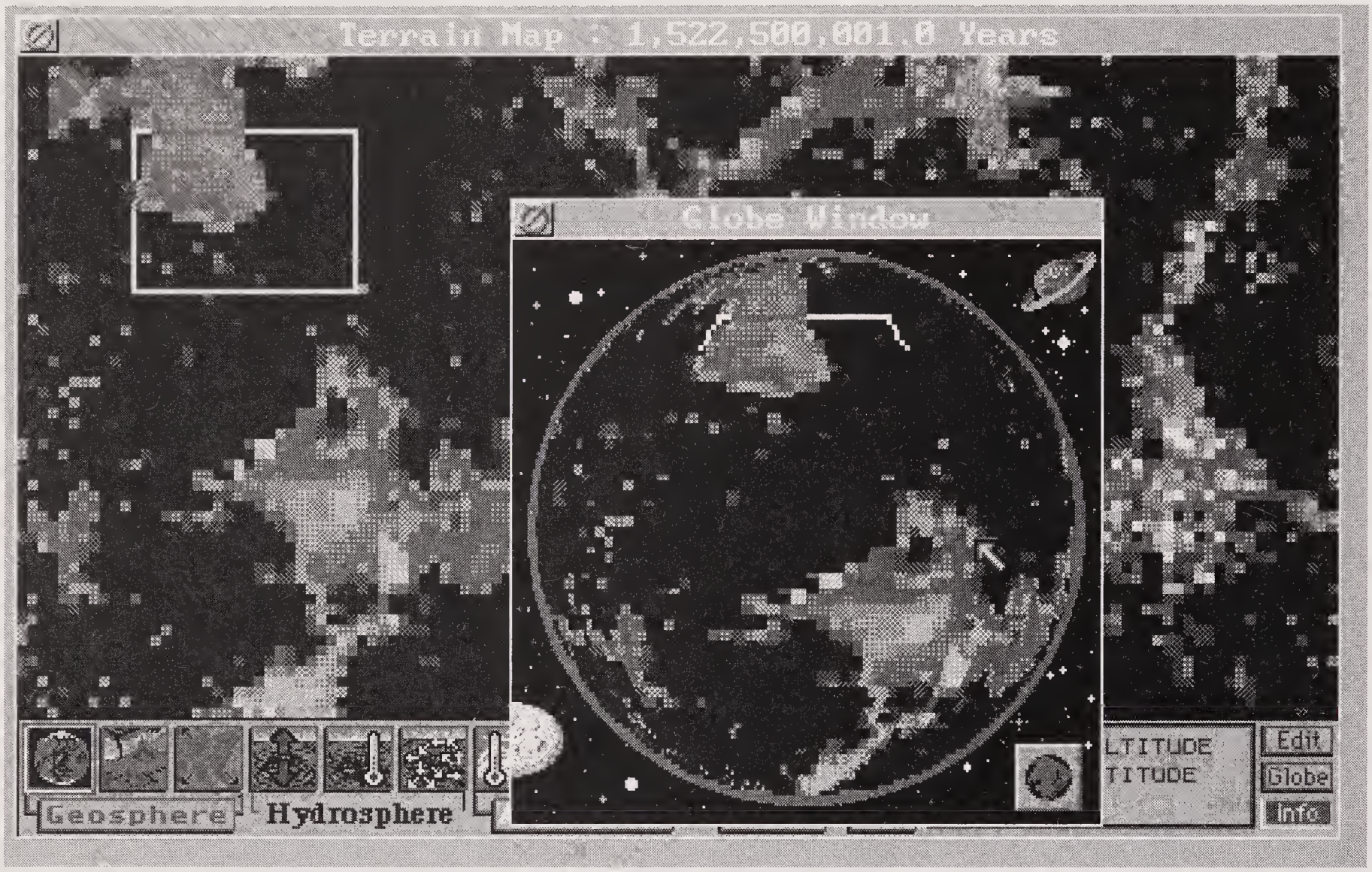
Click on the GLOBE button to view the globe, then double-click to see the core.

17. **To return to the flat map, click again on the GLOBE button.**

You can spend some time now clicking on different buttons to see what happens. However, some parts of the simulation aren't going to work until you get to the real thing. It's time to gather all that star dust and compress it into a densely packed, whirling mass of nuclear energy. It's time to form some balls of rock and gas around it, pick one as a likely site for future development and start the great experiment.



Very Important! Check the Current Tool icon. Is it still set on a disaster, a volcano or meteor or (ugh) atomic test? One danger in SimEarth is leaving the active tool on something dangerous and accidentally setting off a disaster by clicking in the Edit window. Get into the habit of keeping the tool on something innocuous, like the Examine tool (the magnifying glass at the lower right of the six Edit window icons).



In the IBM version of SimEarth, the Globe is a separate window.

It's time to pick a lifeless planet and see what you can do. Are you ready? Then go on to the next chapter and good luck.

In the long run men hit only what they aim at. Therefore, though they should fail immediately, they had better aim at something high.
—Henry David Thoreau

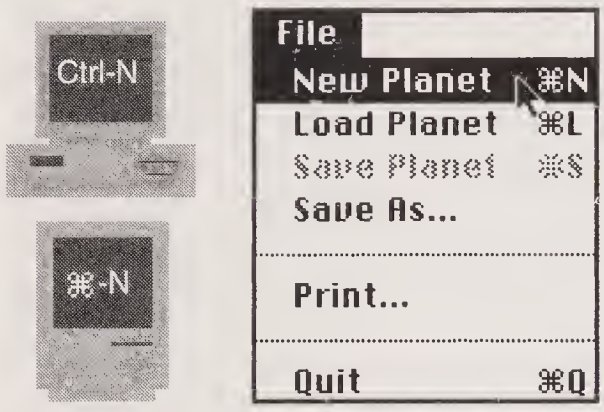
2 / The Primordial Soup Kitchen: Creating a New Planet

Time: 30 minutes
Or: @ 1.5 billion years
Current goals: Form new planet, create oceans, evolve single-celled life.

Now it's time to begin your new job. Don't worry about any damage you just did. It was only on the practice range. Now it's time to trigger the birth of an Earth-like planet of your own. You break open your official G.O.D.S. mission description packet.

"Welcome to your first assignment. You now have ten billion years to promote life, civilization, and interstellar travel. The clock is about to start ticking. Good luck."

That's all it says. Brimming with confidence, you close the packet and get ready to begin. As a hotshot newcomer, you're pretty sure you can trim off five or six billion years easy. Maybe more. In fact, you don't even know how many civilizations you can nurture and send to the stars in ten billion years. You know that the secret is to get the life to



develop quickly, and you'll use many of the tools in your G.O.D.S. toolbox (also known as SimEarth) to accomplish your goals.

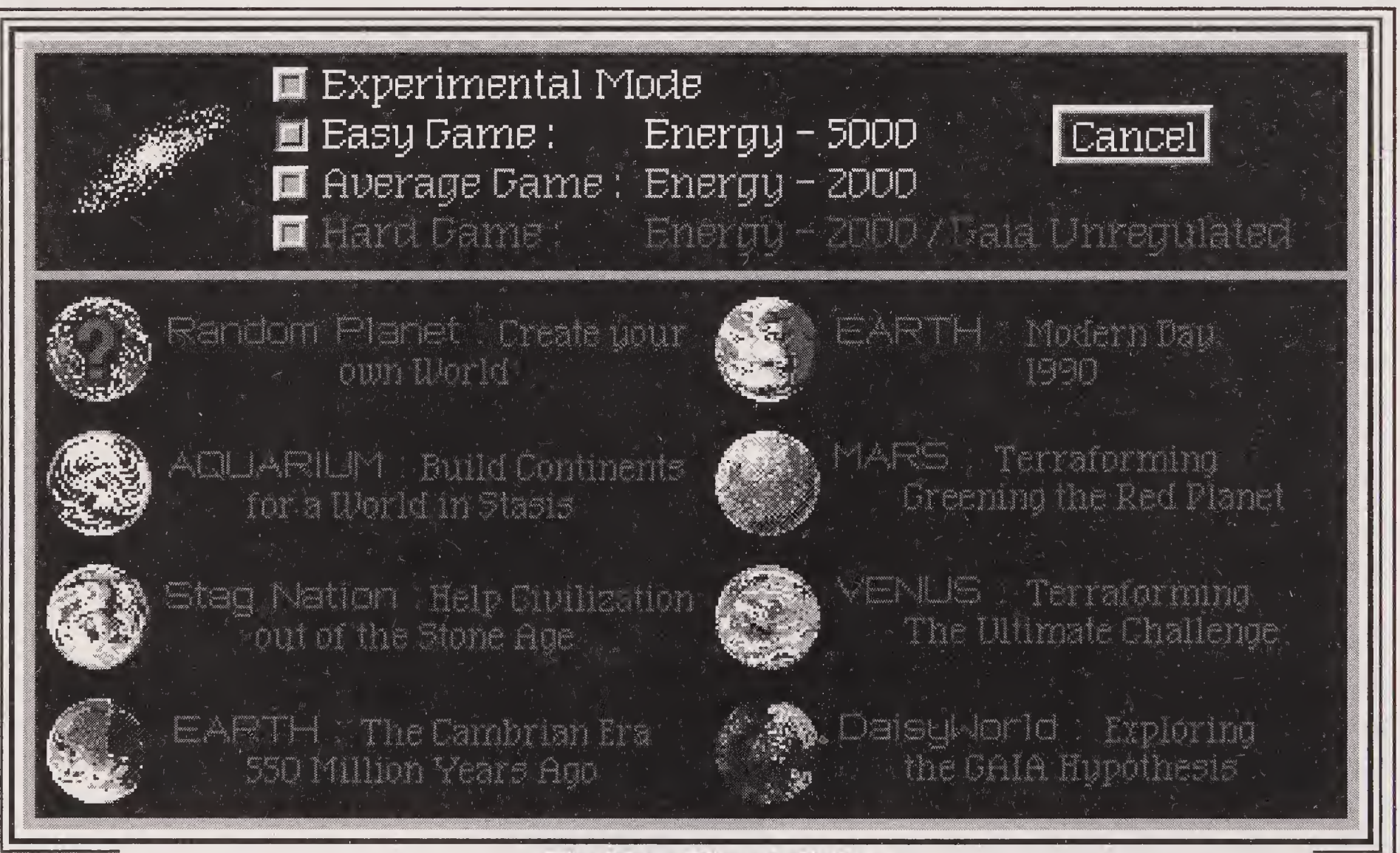
Before you begin, make sure the Current Tool is the Examine (magnifying glass) tool. Click in the Map window and click the Terrain Map icon (the one furthest to the left).

1. **Select New Planet from the File menu or use the keyboard.**

2. **Answer the simple copy protection question.**

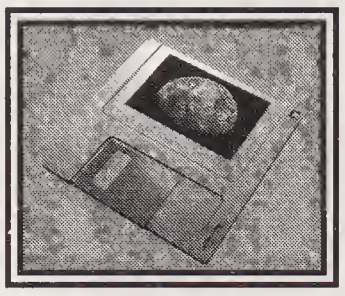
   (You'll find the answer at the back of the SimEarth manual.)

You'll notice that there are four ways to play the game—Experimental, Easy, Average, and Hard. Your superiors at G.O.D.S. have determined that you should start with 5000 EU (Energy Units). Many of the operations you perform using SimEarth's tools cost EU. We'll tell you the cost of each action



The New Planet dialog.

as you perform it. If you run out of EU, you can't do anything until your supply replenishes, which it will do slowly.



THE FOUR MODES

There are four modes in which you can use SimEarth.

In the **Experimental** mode, you have unlimited energy and can do virtually anything you want within the limits of the SimEarth model itself. However, you must reach a more advanced state of philosophical perfection before you can use the Experimental mode.

In the **Easy** mode, you have an upper limit of energy units. Each action you take costs some energy and you can never have more than the maximum (in this case 5000). Energy will slowly recharge over time, however, so if you keep your interference minimal, you'll be all right.

In the **Average** mode, your maximum energy level is only 2000 EU (Energy Units). Some aspects of the simulation are randomized when you begin.

In the **Hard** mode, you have a maximum of 2000 EU, which is like the Average mode, but in this case many of the settings in the model are randomized, and you'll have to stabilize the planet on a limited energy budget. In addition, you don't get the benefit of Gaia regulation. You get to find out what it's like to run the whole show, and it's not a pretty picture. The Hard mode is there to help us appreciate Gaia's support and regulation all the more.

3. **Select the Easy mode by clicking in the appropriate box.**

4. **Now select Random Planet from the list of choices.**

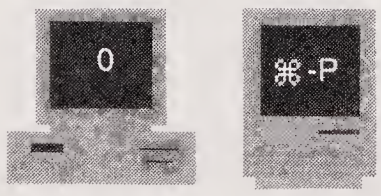
   Don't worry about the other options. We'll get to each of them in time.

5. **Type a name for your planet. Call it *Tutor1*.**

Notice that there are four time periods available. Let's start right from the beginning, with the formation of the planet.

6. Leave the choice on Geologic Period and click on Begin (or press the Enter or Return buttons).

Wait until the windows reset and the Map window shows the molten surface of the new world.



7. Now select Pause from the Speed menu.

Pause is another very useful feature of SimEarth. Even though time stands still in the simulation, you can still access all the tools available in the game. If events are happening too rapidly, Pause the game while you figure out what to do about the situation. Even though you'll be instructed to pause

from time to time, use this feature whenever you want to do some reading. It's better to read first, then watch what your planet is doing.

(The G.O.D.S. Field Manual explains the Pause phenomenon by stating that you have invoked a little-known and even less understood principle of relativity that lets you operate at hyper speeds. G.O.D.S. has developed the technology to allow you to operate at various speeds relative to the planetary frame of reference. In this case, it appears that time has stopped; in fact you are operating at a speed so fast that, for all intents and purposes, it has. There is no penalty for using the Pause mode. Early earthlings attempted to speed themselves up, but they generally paid disastrous prices and often ran out of EU while doing so.)

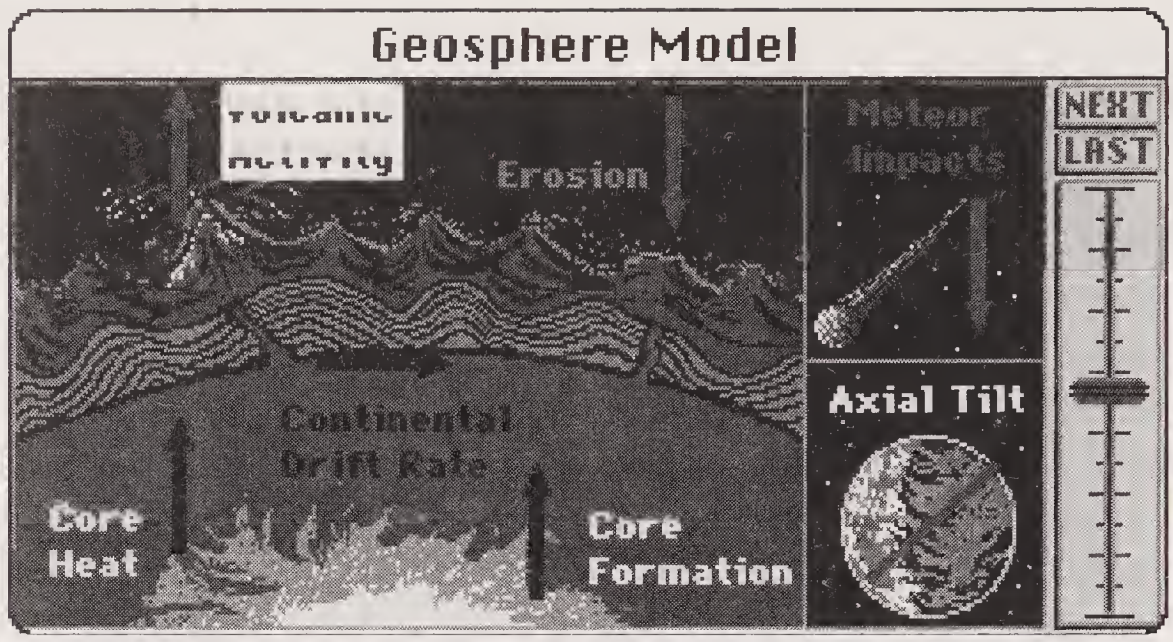
The surface of the world is very hot. Notice the multiple ring shapes on the surface. During the early days of our home planet there were lots of meteors hitting. In fact, the rain of meteors and planetesimals supplied Earth with important elements such as gold, platinum, rhodium, palladium, ruthenium, and others that are more common in meteors than they are in the Earth's crust.

8. Before you do anything else, open the Speed menu and select Absolute Date.

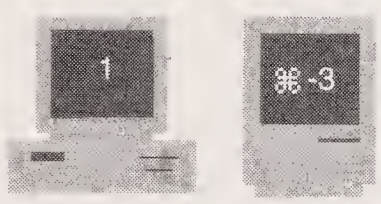
Absolute Date measures the time elapsed from the beginning of the planet's formation and cooling process. We'll measure all events using the Absolute Date.

To understand some of the forces at work here, take a look at the Geosphere Model Control Panel.

9. Open the Geosphere Model Control Panel by selecting it from the Models menu or by clicking on the word Geosphere in the Map window.



10. Drag the Model Control Panel window by its Title Bar to position it where you want it.



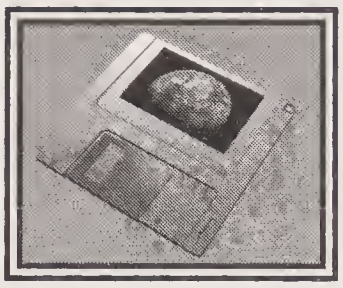
11. OK. Now put the simulation in Slow mode.

Time moves very quickly in the Geographic time period. Each "tick" of the simulation represents 7.5 million years, so the planet will very quickly cool and harden at the surface.

12. When the simulation reaches about 200 million years, Pause the game again while you read the next section.

The Creation of Oceans

The next step in the development of the planet is the formation of the oceans. Because we're impatient Planetary Managers, we'll attempt to speed the formation of the oceans along. There are two ways to do this. One way is to increase rainfall. Increasing rainfall is easy. To do so, you would open the Atmosphere Model Control Panel by selecting it from the Models menu or clicking on the Atmosphere button on the Map window. If one of the other model control panels is already open (like the Geosphere Model Control Panel, for instance), you can click on the Next or Last button in the upper right corner to change models.



THE GEOSPHERE MODEL CONTROL PANEL OPTIONS

There are several options available on the Geosphere Model Control Panel that will affect the development of the planet in this early time. Others have little effect until later. Although we won't change any settings at this time, studying the Geosphere Model Control Panel can help you understand the forces at work during this time period.

- Raising **Core Heat,** for instance, tends to make volcanoes bigger. It also affects the changes of direction of magma flow, which in turn affects how the continents drift.

- **Core Formation** can also affect volcanoes and continental drift by affecting the speed of the magma flow. Increasing the setting for Core Formation causes the core to grow more rapidly. A larger core means slower magma and smaller volcanoes.

- **Continental Drift** lets you set the rate at which the continents move on the magma. Try just watching a new world form with a high Continental Drift rate and compare it to one that has a low rate.

- Raising the level of **Volcanic Activity** will increase the frequency of volcanic eruptions. If you want more land area on your planet, this is one way to get it.

- **Erosion** is the process by which the land is worn down and returned to the air and to the sea. Erosion has the effect of releasing additional CO_2 into the atmosphere as well.

- Increasing **Meteor Impacts** is self-evident. More rocks from space.

- **Axial Tilt** is most noticeable in the modern periods of the planet's development. A more pronounced tilt results in more intense seasonal changes (winter to summer).

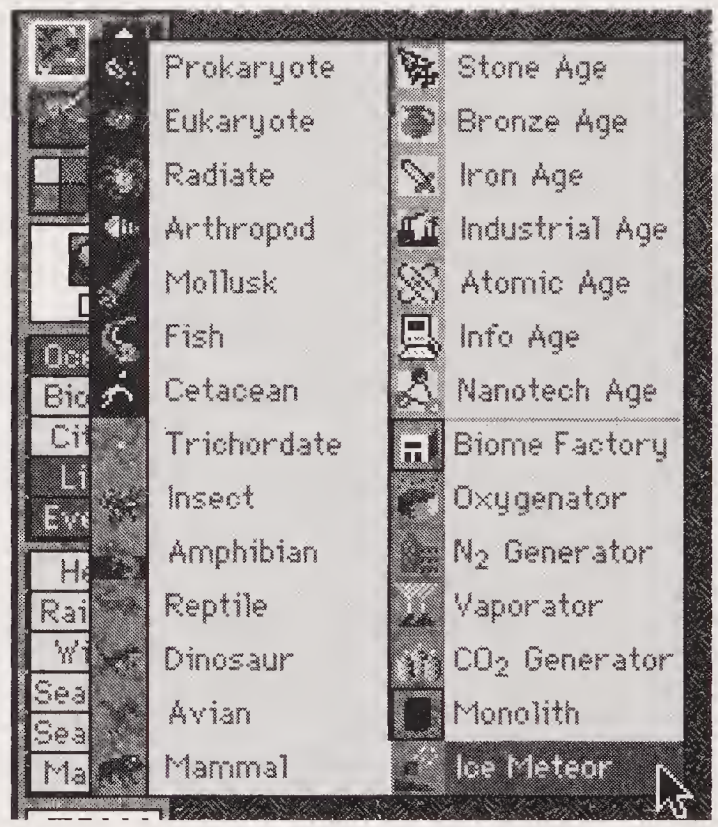
Life is an offensive, directed against the repetitious mechanisms of the universe.

—Alfred North Whitehead

Now you could click on the word "Rainfall" and move the slider on the right edge of the model window. However, let's try a more dramatic way of influencing the formation of the oceans. Leave the Rainfall setting alone for now and:

13. Click and hold on the Place Life icon (on the Edit window, the top/left icon). Scroll down the choices until you come to the Ice Meteor.

On the Mac, Ice Meteors cost 500 EU each (1000 EU on the PC!!!), so you won't want to be profligate with them.



The Place Life Palette.

In the next step, you restart time and the planet will begin to change before your eyes. Watch it develop. You'll see mountains form as volcanoes spit their lava upward onto the surface. Meteors crash into the surface constantly, further reshaping the planet. As this new world cools, the terrain will take shape. The lighter the color of an area, the higher it is. You can guess what the continents will look like from the shapes and contours on the map, but without oceans the configuration of the land is hard to make out. Pretty soon though, the water will condense out of the air and form the oceans, the cradle of life.

14. When you are ready, start the simulation again at Slow speed.

Now you'll wait until your planet is about 270 million years old (don't worry, it won't take

long to get there), and, unless you already see water forming on the planet, you'll drop a single Ice Meteor onto the surface.

Using more than one ice meteor can get you into trouble by raising sea levels too high. This can have a significant and detrimental effect on the later development of your planet. So drop no more than one of them.

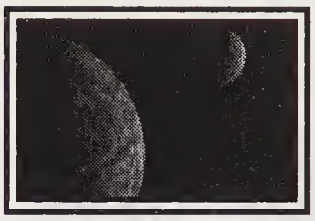
15. Drop an Ice Meteor at 270 million years (unless liquid water is present).

16. Pause when the oceans have formed. (There will be an announcement, but you'll also see a lot of water.)

If your oceans don't form within 367.5 million years, you should start over. Do not drop another ice meteor! It doesn't take long to begin again. Although you can have successful planets with late-forming oceans, the chain of events that we're looking for will be more likely if you keep within certain limits. Therefore, you may have to start over from Step 1 until you get a cooperative planet. It shouldn't take long, and you may even be lucky and get a good one from the start.

By 367.5 million years, the oceans should have formed. If they don't, it's nothing you did wrong. That's just the way planets are. Sometimes they take a little longer. The earliest we have made oceans appear is at 232.5 million years, but that takes a bit of luck and a lot of cheating with ice meteors and high rainfall settings. The trouble is, forming the oceans that early doesn't necessarily guarantee that life will get a quicker start, or that your planet will necessarily favor life. Once again, to repeat an old axiom, it's risky to mess with Mother Nature. On the other hand, the earliest ocean we've had spontaneously develop was at 202.5 million years.

There's a fair chance that the oceans would have formed by 367.5 million years without your help, but planetary development is somewhat unpredictable, and sometimes it takes hundreds of millions of years longer. Since

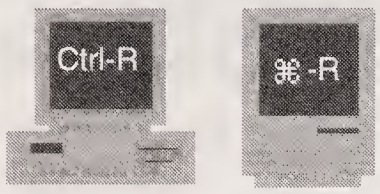


How the Oceans Formed

During the formation of the crust, volcanic activity continually sent clouds of gases into the atmosphere. Both hydrogen and oxygen were common among the elements of the early Earth, and they naturally combined into one of the most miraculous compounds in the known universe. That compound is water. Water vapors, formed during the outgassing from the inner Earth, combined with water that reached the planet during cometary collisions and, as the Earth cooled, that water vapor condensed and became rain. The flood that followed must have made Noah's deluge look like a mild drizzle.

Eventually the oceans covered almost three quarters of the planet. They dissolved all kinds of compounds–salts of various kinds, iron (which was freely dissolved in an atmosphere lacking in free oxygen), and a soup of amino acids and other organic chemicals that formed in the hot, turbulent conditions of those early days known as the Hadean period.

you're in a hurry to get to the stars, it's OK to speed the process up a little by using an ice meteor.



17. Still Paused, open the Report window (from the Windows menu or using the keyboard).

You'll see the Geologic Report window. Notice that certain information is available in this window. You'll be checking it from time to time. Right now, check the current task. It says "Evolve Multicellular Life." Notice also that the current situation (the viability factor) is poor for life. However, some theories suggest that life evolved very quickly after the oceans formed. We'll go with that concept.

The First Appearance of Life

Left to its own devices, your planet might take several hundred million years more to evolve life. It's all right to wait and watch the continents drift in the meantime, but if you're still with us, still on the fast track, why not just drop the seeds of life right in there and watch what happens?

18. First close the Report window unless you have plenty of room to keep it open and out of the way.

This is also a good time to save the planet. You should be sure to save often. Then, if things don't go quite the way you planned, you can try again.

19. Select Save Planet from the File menu or use a keyboard shortcut.

Saving the game doesn't cost you any energy units. Up to this point, your game wasn't saved, even though you named it when you first started. Now there is a saved planet called Tutor1 on your storage device.

If, for some reason, you aren't happy with the results of the next few steps, or you want to try another life-

formation strategy than the one we use here, you can go back and try again. Choose Load from the File menu and select Tutor1. You can start from this same place as many times as you want.

The G.O.D.S. Field Manual doesn't explain how they do this, but they insist it isn't done with mirrors. The technology is too advanced to explain until you reach Planetary Symbiote status—a highly evolved philosophical state of mind well beyond your present PM status. It may have something to do with parallel universal Z+ manipulation. But that's just a guess.

20. Click and hold the Place Life icon again and this time pick the Prokaryote (the first life form).

The Place Life icon is the same one you used to select Ice Meteors. Prokaryotes are a bargain at only 35 EU each.

21. On the Map window, click on the Life Display map icon.

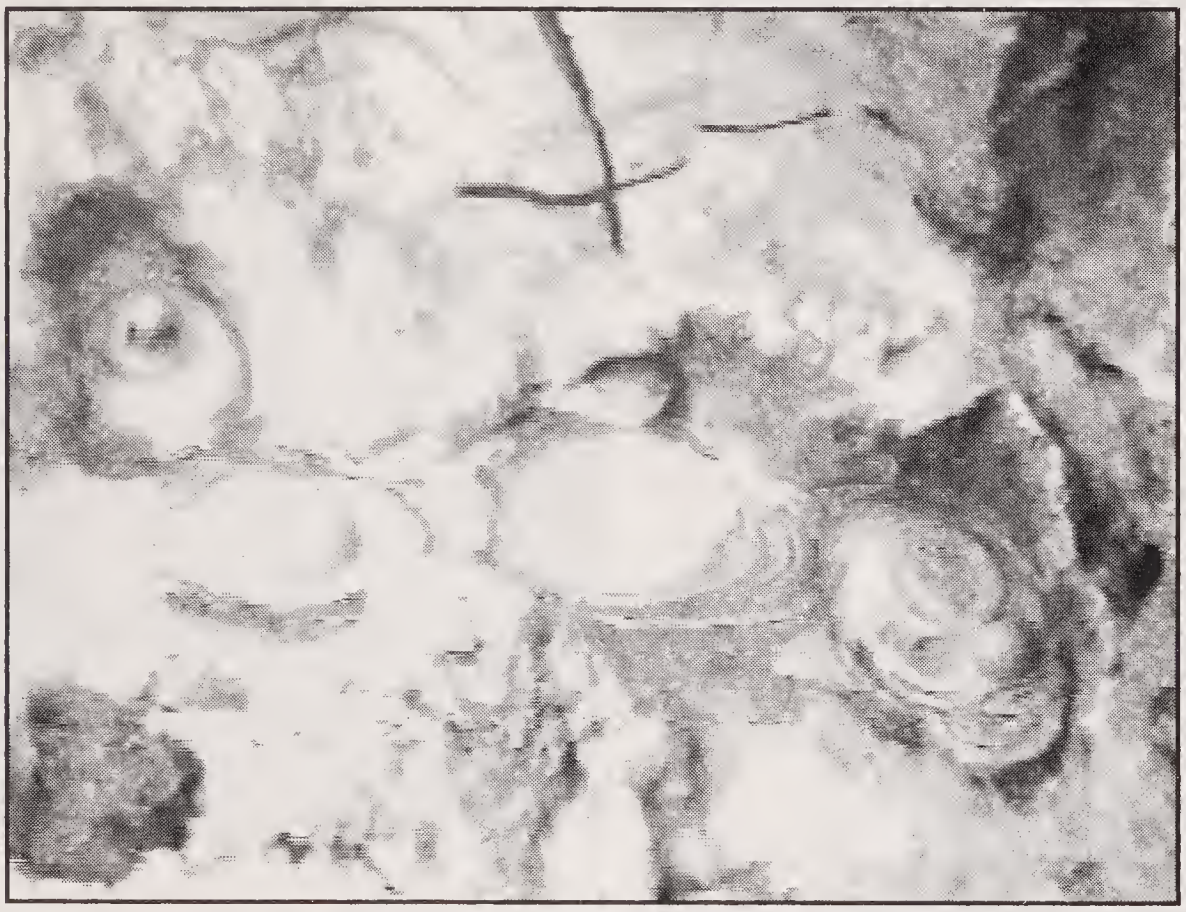
The Life Display map icon is on the Map window in the Bio group. It shows miniature pictures of animals. At first, nothing will appear on the map other than the new continents and the ocean.

22. If you have room on your screen, open the Gaia window (from the Windows menu) and watch what happens in the next step (after the next special section).

Some Theories on the Origin of Life

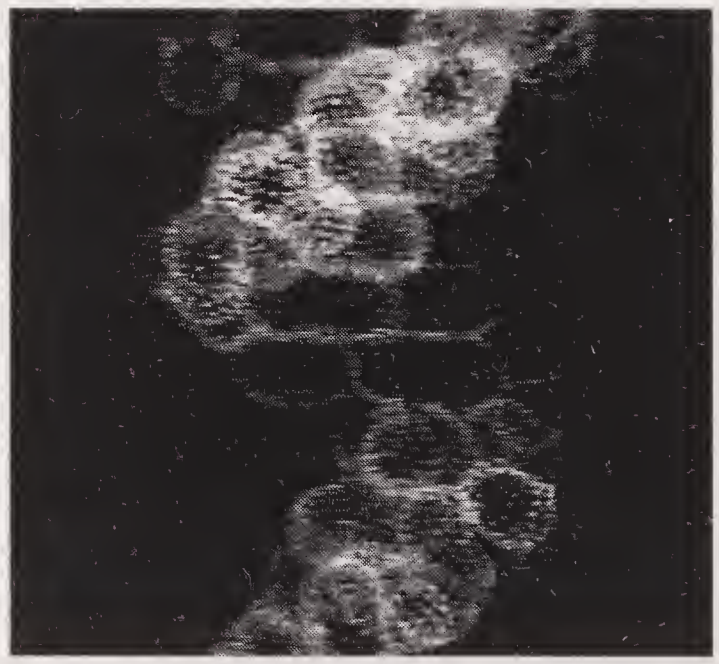
Nobody knows how life really started on Earth. They are pretty sure, however, that it started very soon after the planet cooled. So far, the earliest evidence of life on Earth dates back almost 4 billion years. Scientists believe that the planet formed about 4.6 billion years ago, so that means that life formed very quickly, geologically speaking. If you consider that for probably 500 million years, the planet was too hot and violent to support life, it is a considerable miracle how quickly life must have formed.

From laboratory experiments, scientists have been able to reproduce their best guess of the conditions existing before life evolved. The likely combination of elements and conditions, with volcanic eruptions spewing hydrogen compounds and carbon dioxide, lightning flashing over the landscape, and the constant churning and heat, probably helped create the long-famous "organic soup" of amino acids and other organic compounds that are believed to be the necessary building blocks to life's formation.



Did bubbly clay help make DNA?

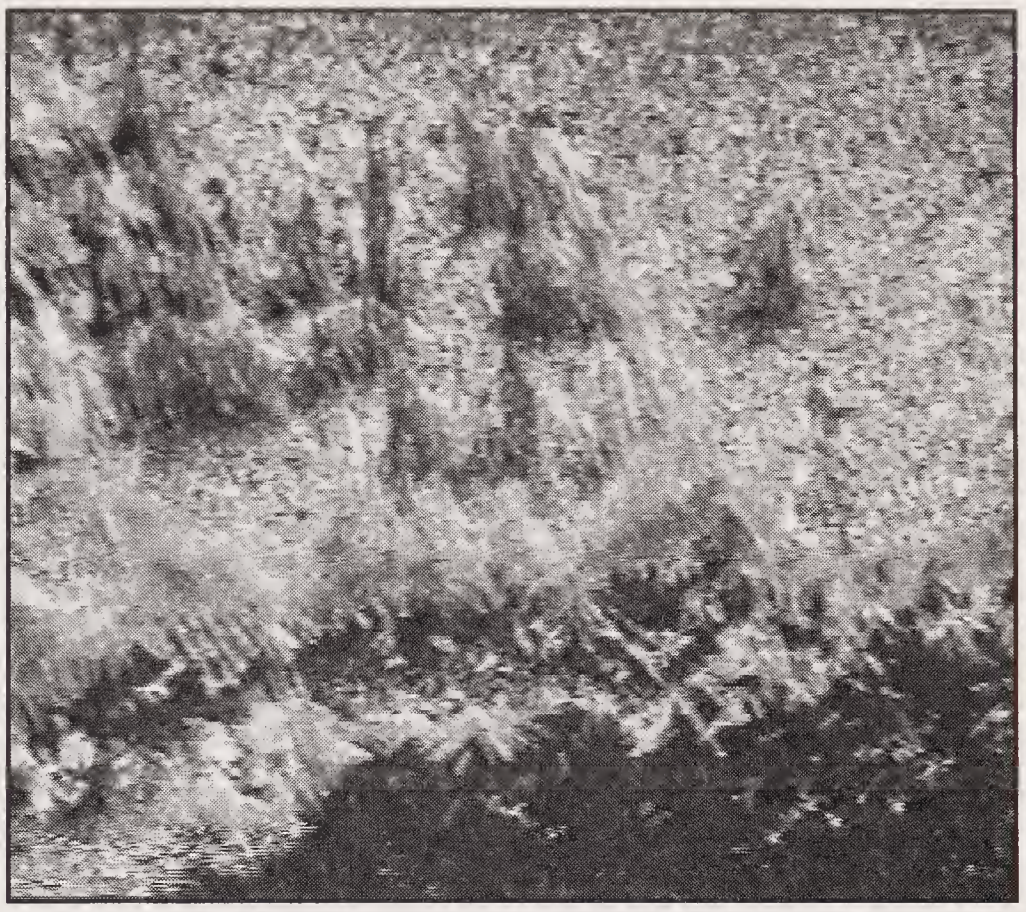
Still, theories dating that far back in time are just that--theories. One such theory is the so-called "open faced sandwich" theory. Some scientists are looking at certain clays like those found in hot springs in Iceland. These clays form themselves in a distinctive spiral crystalline pattern and the theory suggests that organic molecules drifted into the twists and turns of these crystalline spirals. In the primordial soup, the organic molecules eventually began to form a spiral pattern using the clay spiral as a template. In this way, the spiral-shaped double helix of DNA may have been born. Once DNA was formed, its ability to replicate itself assured its continuing survival. In a way, the DNA itself was alive, but through unknown processes the DNA combined with other organic structures to form the earliest bacteria. How this was done is still a mystery, but see the sidebar on prokaryotes



The DNA Helix.

a little later in this chapter for one theory. And of course, if this theory is correct, then all life sprang from clay, rather in accordance with Biblical views.

Another idea involves the undersea vents first discovered in 1973. These remarkable deep sea vents are the results of plate tectonics. As the plates move, they expose new sea floor and, at the same time, they allow the molten rock and minerals to come in contact with the water deep in the sea. The environment at these vents is unlike that of any other place on Earth. The pressures at the bottom of the sea are so enormous that most people once thought no life could survive there. Moreover, the most important ingredient of life, sunlight, can't reach to those depths, so photosynthesis is impossible.



Clay crystal structures in high magnification.

Today, bacteria live in boiling water like this hot spring in Iceland.

At the vents, however, there is abundant life. It's not life as we know it on the surface. It doesn't depend at all on the sun for energy, but receives all its resources directly from the depths of the Earth. The bacteria that live there feed on the abundant hydrogen sulfide that spews from the vents. These bacteria form the basis of the food chain for a whole ecosystem that includes giant tube worms, giant clams, strange white crabs, and an assortment of other unique oddities.

But what do these vents have to do with the origins of life? Some scientists believe it is very possible that life evolved in just such environments, and only later spread out into the upper world of sunlight. It is even possible that during times of extreme catastrophe on the surface, for instance when huge planetesimals (meteors or comets) impacted the Earth, most surface life may have died. Some scientists postulate that as much as 90% of all life may have perished in some of these past collisions. Others think all surface life may have died. This makes the vent creatures even more significant because if the latter theory turns out to be correct, then all life today may have evolved from the life around these vents--the only life

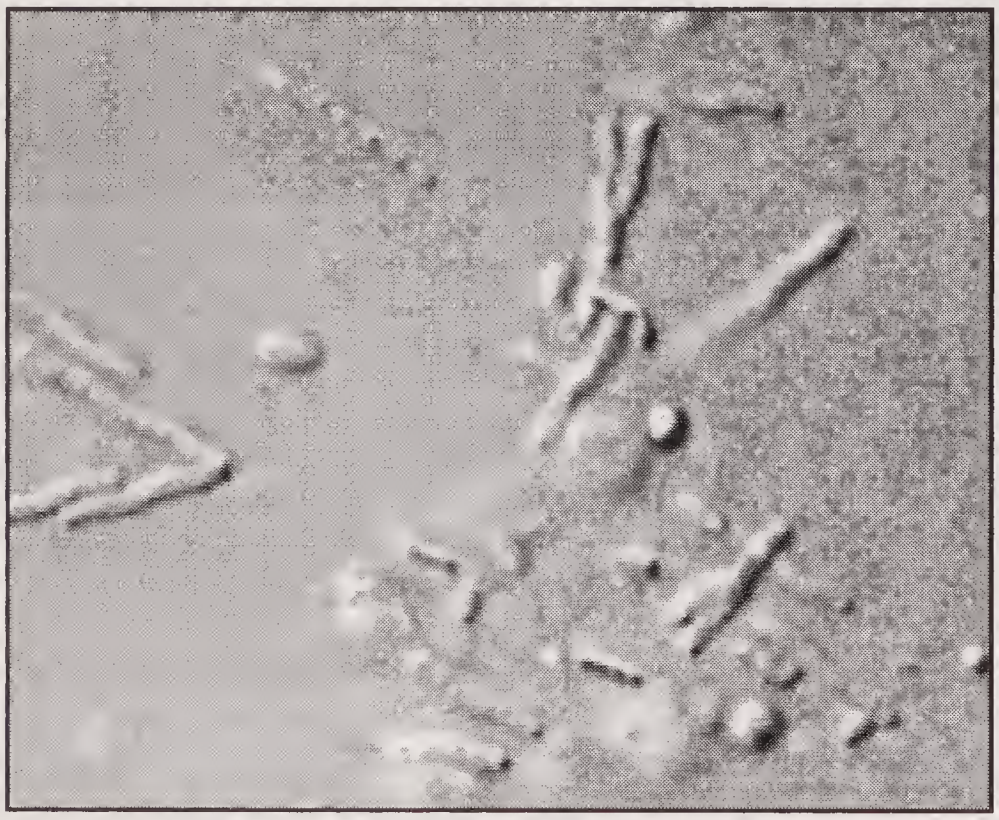
on Earth that does not depend, directly or indirectly, on the Sun for its survival. The open faced sandwich theory and the vent theory are not mutually exclusive. In fact both theories may be correct, and the clays in question may have first formed around undersea vents. Again, it's speculation.

Still another theory, though one that does not represent the majority opinion, is that life actually originated on meteors which carried some kind of encapsulated virus through the depths of space until they found a hospitable environment on Earth. And, of course, there are even less reputable theories that life on Earth is nothing but a great experiment carried out by a superior race of aliens. Most scientists lean toward some variation of the first two theories, but it's always interesting to speculate, and certainly our studies of the natural world are always surprising us. It was only a few decades ago that people generally found the idea of moving continents and plate tectonics preposterous. Now we know for certain that the continents do move.

It is impossible to say that the truth will never be known. Some as yet undiscovered clue may lead scientists to a definitive answer, but for now, we are looking back a long distance (in time) and our clues are meager at best. All we can say with some certainty is that life did form, and it did so rather quickly after the Earth cooled and the oceans formed.

More About How Life Started—Prokaryotes

The world was very different then, back in what is called the Hadean and later the Archean periods of Earth. During the Hadean period (the hellish period), the planet was simply a cauldron of molten shifting matter. It was gradually cooling and outgassing to form an atmosphere of mostly carbon dioxide with traces of other gasses like methane and various hydrogen compounds. And, as it cooled, abundant hydrogen and oxygen combined to form that most miraculous substance--water. As the planet cooled, water rained down on the surface and eventually oceans formed.



Primitive cells.

About the time that the first primitive cells evolved, the landscape would have been very different from what we see today. James Lovelock in *Ages of Gaia*:

"I suspect that from an orbiting spacecraft we would not have seen the familiar blue-and-white sphere with glimpses of land and sea beneath an aerial canopy. More likely, the view would have been of a brownish-red, hazy planet; like Venus or Titan, too obscured to see the surface below. The sky that now we see as blue and clear results from an abundance of oxygen. Oxygen is the permanent bleach that clears and freshens the air."

Lovelock continues to describe a world with reddish-brown oceans, laden with dissolved iron, not yet oxidized, and an orange sun looking down through a pinkish sky. It would have been a scene out of the imagination of some science fiction writer's fantasy. Plopped down in the middle of that world (with the appropriate breathing and life support equipment, of course) no Earthling would immediately recognize it as the same planet we now call home.

If the theory of the crystalline clay spiral is correct, then DNA and RNA molecules were formed and became self-replicating. But how did these complex, but essentially non-living molecules become what we now know as bacteria, with cell walls and discrete structures? One theory suggests that a by-product of the replication process of the DNA was a kind of lipid, a fatty substance. In fact, lipid-like compounds are also found in meteorites, which suggests that yet another essential component of life may have been space-borne. At any rate, as the primitive DNA continued to split and reproduce, these lipids may have build up around them until, finally, they surrounded the DNA, forming a wall. In this way, the first cell walls may have formed. Laboratory experiments have been able to reproduce this effect, though no truly living cells have resulted so far.

The process from a simple, walled-in DNA helix to a functioning prokaryotic cell is still a mystery. Basically, however, prokaryotes are single-celled creatures lacking a nucleus. They are about as far down on the evolutionary ladder as you can get and include various types of bacteria and algae.

This is a very simplistic view of the process, but one that at least gives us some idea how the transition from a floating soup of strange organic compounds might eventually have led to something we would recognize as life.

Over time, as billions of these simple cells were formed, mutations and adaptations certainly occurred, and eventually some cells found new ways to find food. Those cells which didn't depend only on the surrounding soup of nutrients would have had an advantage, and the first cells that discovered how to harness the energy of the sun to help break down chemicals into the nutrients they needed to continue to exist and self-replicate were at a great advantage.

The earliest photosynthesizers may not have used carbon dioxide as modern plants and photosynthesizing bacteria do today. They may have used hydrogen sulfide, which takes less energy to break down. However, in time certain bacteria "discovered" how to use sunlight to break down the even stronger bonds between hydrogen and oxygen in the far more abundant compound we know as water. This one innovation may be considered among the most important in the history of life. With endless sunlight and water, these new photosynthesizers could thrive almost anywhere, and they quickly became the dominant type of microbe. As one author has described them, they became like single-celled Attila's Huns with the battle cry of "Sun and sea, sea and Sun." Today, the ancestors of these earliest creatures still exist. They're called cyanobacteria (because of their blue-green color). These are the ancestors of all green plants that have existed throughout Earth's history. Other prokaryotic creatures existing today include amoebas and algaes.

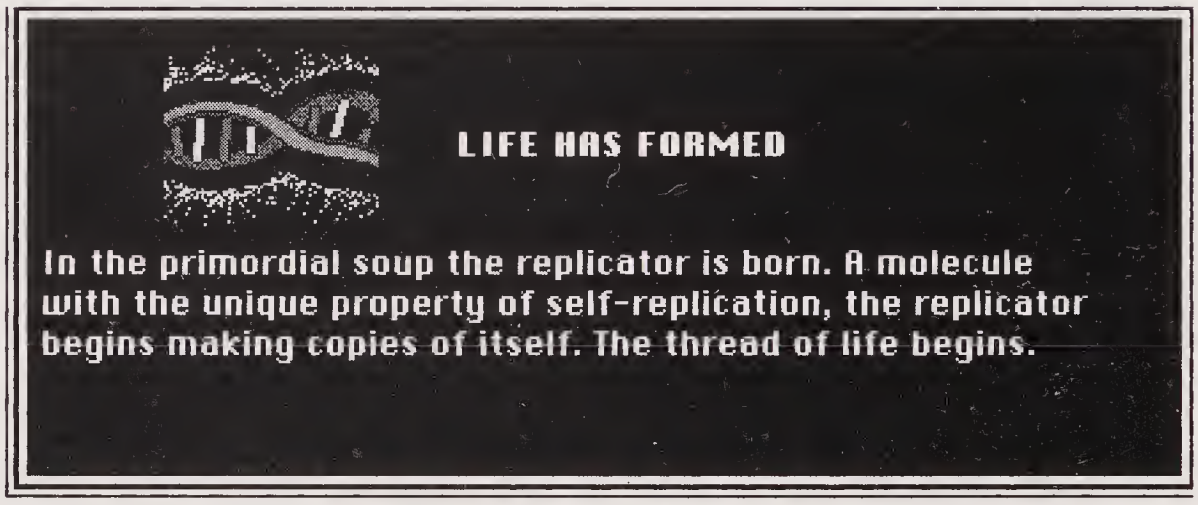
The advent of the cyanobacteria was to bring on a new, and devastating crisis to the Earth. For more on that, see "The Oxygen Crisis" later in this chapter.

23. Restart the simulation at Slow speed.

24. Click in the Edit window, anywhere in the ocean.

Depending on which version of SimEarth you're running, you may have dropped a prokaryote, or you may need to click once again to do so, the first click only activating the window.

Gaia will wake up! She's alive!!!

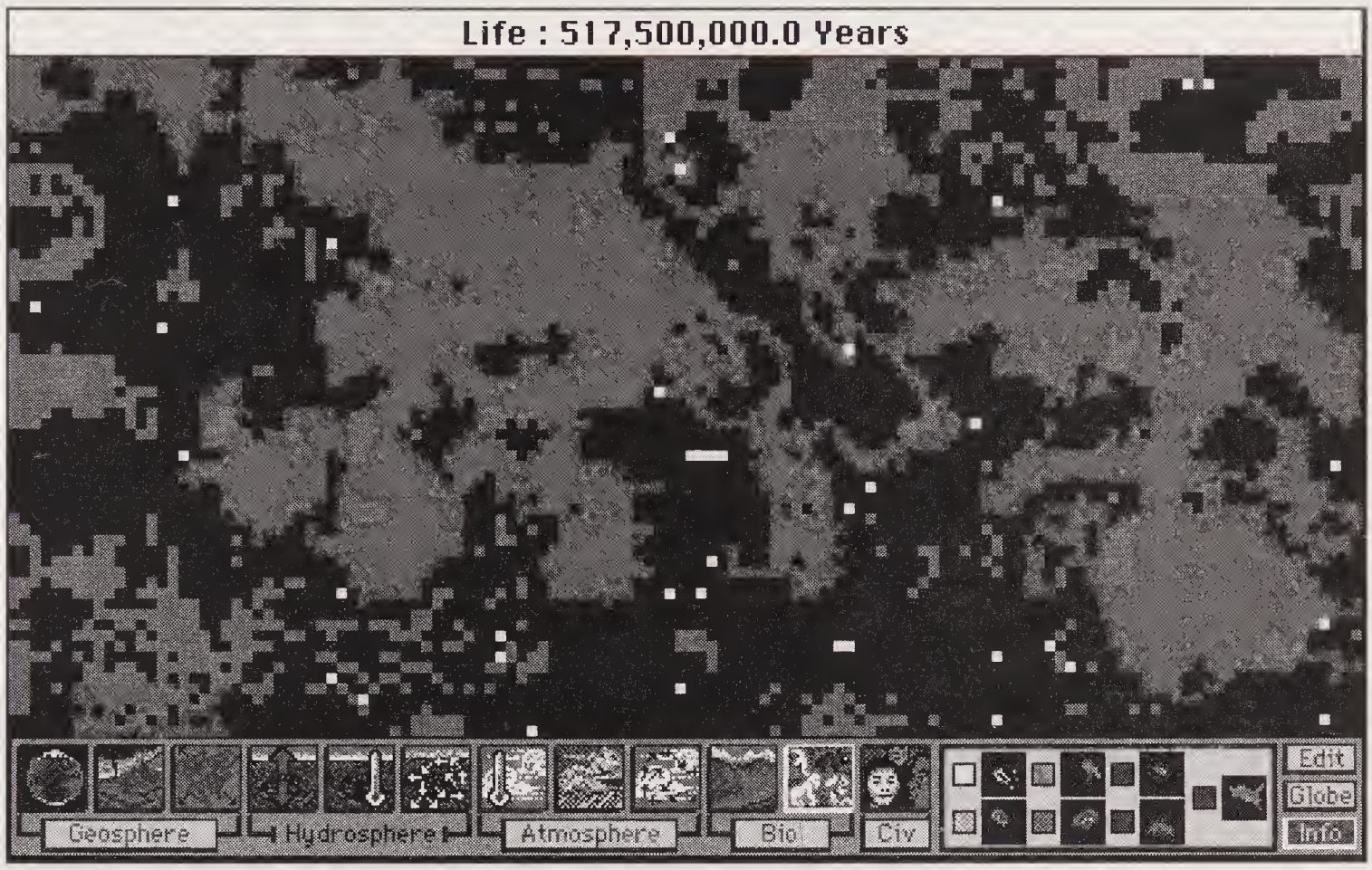


You'll see the little prokaryote microbe in the Edit window and you'll also see a little square on the Map window. Watch how fast the little buggers multiply. Pretty soon they'll be all over the place, covering the oceans.

As you watch, some of the squares will change color or shade while the creatures in the Edit window will change form. They are evolving into more advanced prokaryotes.

25. You may want to let the planet develop for a few million years—though not more than 50 million—then Pause while reading the next sections.

For a successful start to life, you'll need a world with vast oceans. If there is a lot of land on your planet, and



Prokaryotes on the Life map.

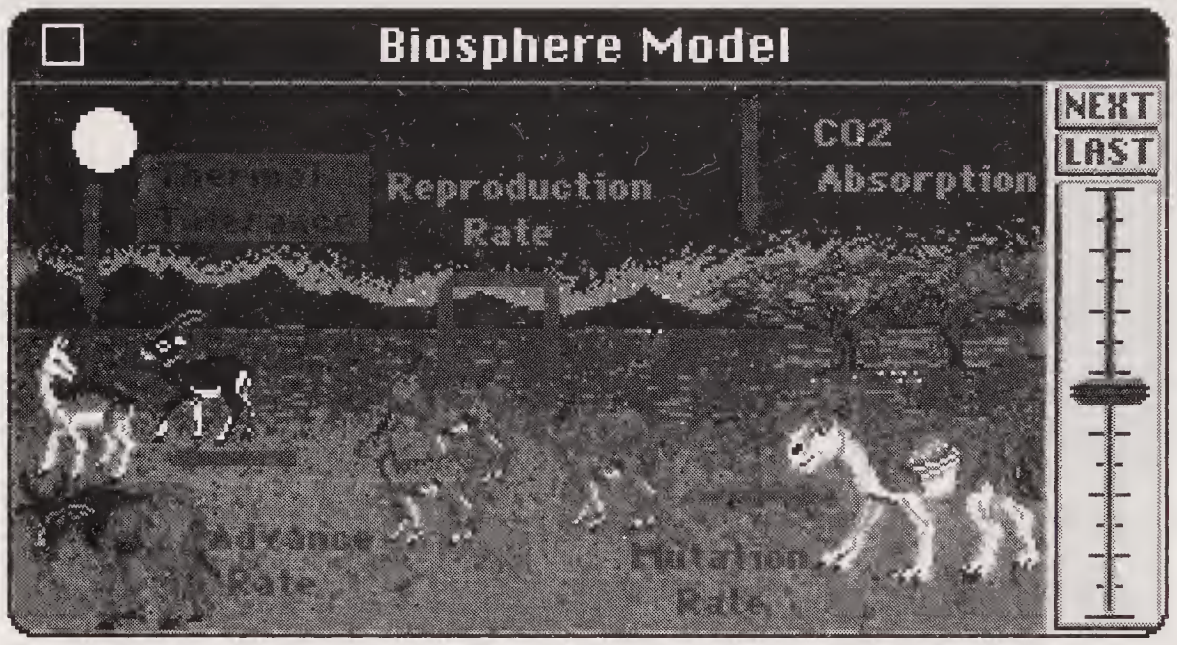
the ocean area is small, the advancement of life will be slower. On the other hand, on some planets ocean levels may rise over the eons (often around 900 million years), and for future evolution, a decent amount of land will be needed. Our original planet Earth was covered with about two-thirds water. You can affect ocean levels by using the Rainfall slider on the Atmosphere Model Control Panel. You can form new land with volcanoes, or by tweaking Volcanic Activity and Core Heat on the Geosphere Model Control Panel. Because the Random Planet simulation is, in fact, randomized, not every attempt will succeed equally. Keep following the steps outlined here, but, if things don't work out well, be prepared to start over. World building can be a rough business sometimes. Not every world that tries the experiment of life will necessarily succeed to your standards.

If you have a planet with too much land, you can turn up Erosion. A lot of land will be carried into the sea, forming vast continental shelves. But watch out for

rising CO_2 levels. Or try dropping another Ice Meteor. That will raise water levels and perhaps carve away a piece of a continent. Sure, it's a radical solution, but it may help your microbial life to thrive.

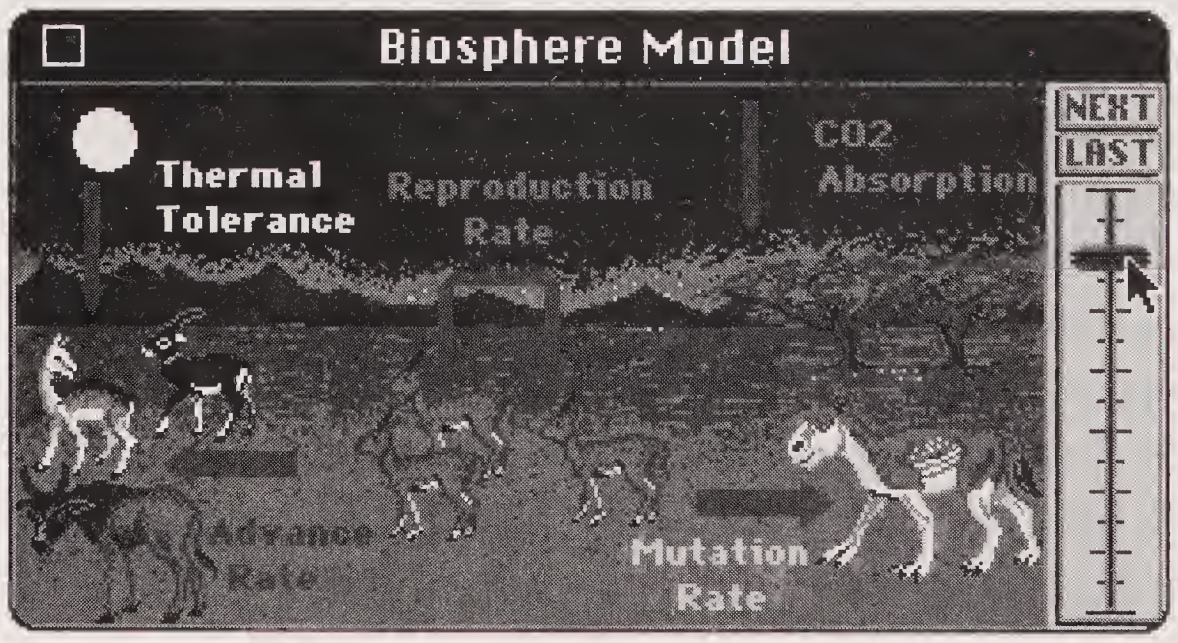
If you want to speed up the evolution of life on your planet, try this:

26. Click on the NEXT button until you see the Biosphere Model Control Panel or select the Biosphere Model from the Models menu.



27. Click on Advance Rate (or Split Rate) and raise its level by a couple of notches.

Changing these settings costs 250 EU.



Now you've instructed Gaia to make your creatures advance quicker to higher forms of their species. The Mutation Rate option would cause them to jump to new species faster, but that isn't needed right now. Be careful about raising the Reproduction Rate, though. You may find life gets very crowded which can make it harder for new species to gain a foothold (or, lacking feet, perhaps a pseudopod-hold).

28. Restart at Slow speed and continue reading.

29. If your planet reaches 600 million years before you are finished reading, Pause again.

At some point the first complex forms of life should evolve. The Eukaryotes were the first to form cell membranes and specialized organs. Eukaryotes were, in fact, collections of prokaryotes that became specialized within one cell wall. This was a major step in the evolution of life.

Before continuing with the next few steps, why not save the game again?

30. Choose Save As from the File menu and rename this version *Tutor2*.

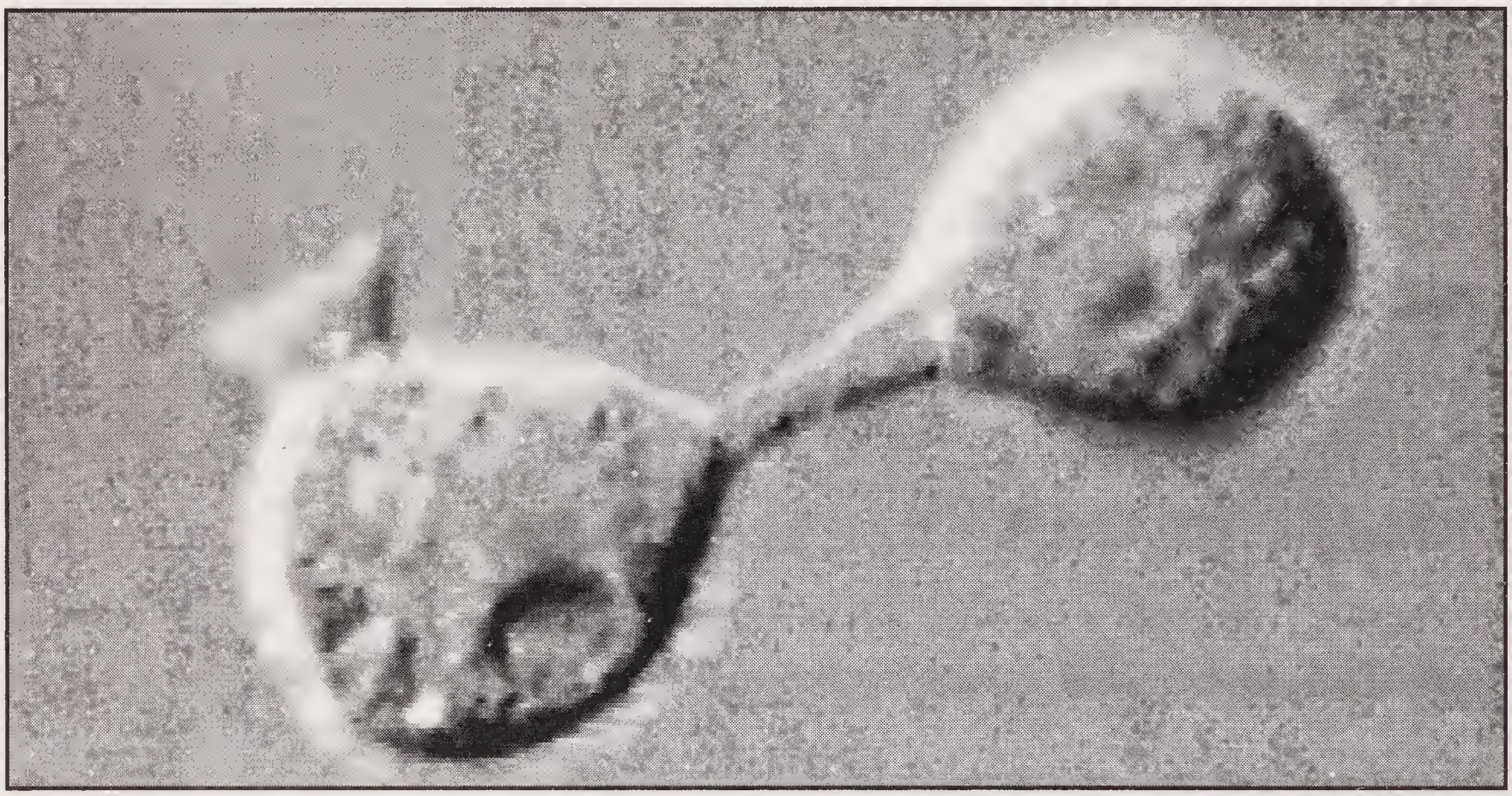
The Oxygen Revolution

The prokaryotes "ruled" the Earth for billions of years, and during that time they evolved and "discovered" new tricks (actually new sources of energy). The result of using these new sources of energy was a new form of byproduct and a massive pollution event. The new energy, gathered by a process called photosynthesis, came from the Sun. The polluting byproduct was oxygen, a rare substance in the atmosphere of the early Earth.

Important SimEarth Note: Although it was the simple prokaryote that first discovered photosynthesis, SimEarth has made a certain distinction here. As far as this simulation is concerned, all prokaryotes are

The First Complex Cells—Eukaryotes

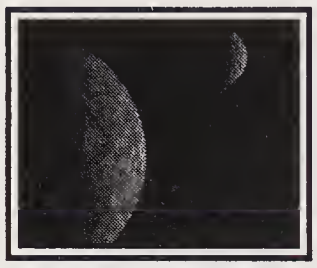
Whether the designations of prokaryotes and eukaryotes as described in SimEarth are accurate, they do differentiate a major difference among the cells that eventually led to the evolution of all life on our planet. The essential difference between a prokaryote and a eukaryote is the presence of specialized "organs" contained within the cell membrane, in particular the nucleus and the mitochondria.



Prokaryotes ruled the world for a very long time, more than a billion years. It was only about two billion years ago that eukaryotic cells, cells with nuclei, first formed. And since the prokaryotes still exist in our world, that makes them by far the most successful form of life ever to exist.

How did the first eukaryotes form? The most probable answer is that one prokaryote absorbed another, but rather than "digest" the second cell, they formed some kind of symbiotic relationship. The result is that, in time, the second prokaryote developed a specialized function, eventually becoming a nucleus which contained the genetic material for the new organism that resulted. Other symbiotic results would have resulted in the various "organelles" of the modern eukaryotic cell, in particular the mitochondria which do the breathing for more complex cells (such as the ones that form our bodies).

Although the exact process that led from prokaryote to eukaryote is not known, given the billions upon billions of prokaryotes that lived and died and reproduced over more than a billion years, the likelihood is that many strange "experiments" were performed by chance, and that this one finally worked. It was the evolution of the eukaryotic cell that eventually made possible the multi-celled organisms that followed, including simple creatures like microscopic hydras, larger beasts like llamas and sharks, and, of course, humans.



THE GREAT POLLUTION EVENT: OXYGEN

Early living cells probably lived in a sort of soup of nutrients. However, as they multiplied, they may have begun to face difficulties finding the organic molecules on which to feed. Life may even have failed, died out from starvation, and started again. We'll probably never know. However, some innovators existed even back then. They discovered a source of energy that was virtually inexhaustible. It was sunlight.

The earliest photosynthesizers probably got essential nutrient materials from the same thinning soup as their predecessors, and their fate might have been an unhappy one if that is where they had remained. But some clever photosynthesizer also came up with a new source of the critical element hydrogen—hydrogen sulfide. This common volcanic gas was in plentiful supply early in the Earth's history, which means it wouldn't have been a very pleasant place for humans.

Perhaps a hundred million years later, give or take a few million, another new idea, an even better idea, was hatched from the unconscious "mind" of Gaia. Instead of using the common, but not all that common, hydrogen sulfide molecule, why not use another simple molecule that contains hydrogen—hydrogen dioxide (water)? Even though it took much more energy to separate hydrogen from water, the supply was virtually limitless. The possessors of this secret were called cyanobacteria (cyan for their bluish green color).

As these new photosynthesizers swept across the planet, they began to produce oxygen. When the hydrogen was separated from the hydrogen dioxide molecule, the byproduct was oxygen—a waste gas. At first, it combined with other materials in the air and water, especially with iron, which up to then had existed in water as ferrous salts. Oxygen reacted with this iron, forming iron oxide (better known as rust), and deposited this iron oxide on the sea beds in thick bands that can still be seen in today's Earth. These bands of iron, the earliest of which dates back 3.8 billion years, were much later to be called "ore" and be collected to make iron and steel implements.

Eventually all the oxidizing substances had combined and more and more oxygen found its way into the atmosphere. This change of atmosphere was poisonous to the early anaerobic life forms, forcing them to find new places to live—places free of poisonous oxygen. In time, they found places deep in soil and mud, or in the guts of animals, which is where they are found today.

Meanwhile, oxygen levels continued to build until the high oxygen content of the atmosphere even threatened the cyanobacteria themselves. In a very real sense, this was the biggest pollution event in Earth's history. It took more adaptation and innovation for life to learn to tolerate this reactive burning substance, but eventually, as one writer has put it, life learned successfully to "play with fire." From these early steps came the more advanced use of oxygen—respiration—which animals and humans have developed to turn this oxygen into energy.

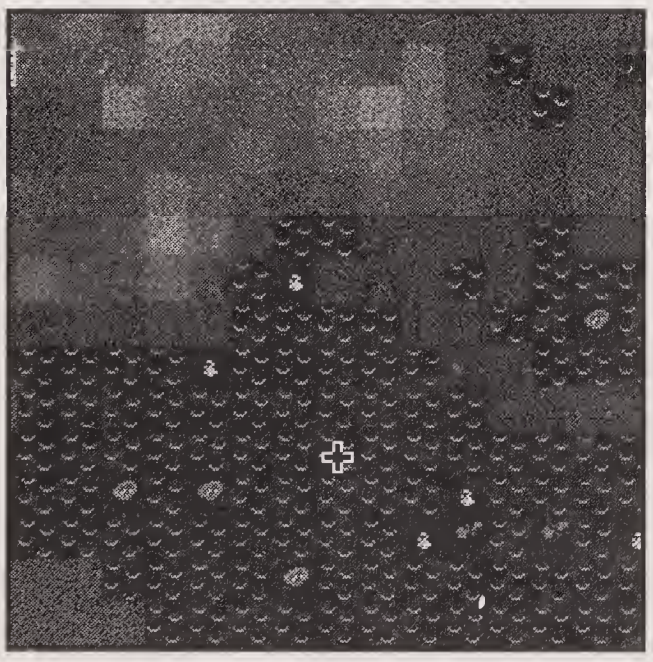
This aerobic "revolution," brought on by the development of photosynthesis, changed our atmosphere from anaerobic (little or no oxygen) to aerobic (significant oxygen content). It completely changed the world and set the stage for the rest of our history.

anaerobic. None of them produce oxygen. All eukaryotes are photosynthesizing and do produce oxygen. Therefore, to see the dramatic shift in atmosphere for yourself, you'll need eukaryotes.

You can watch the amazing oxygen revolution take place on your computer screen. But first you'll need eukaryotes (see Important SimEarth Note). If you wait patiently, eukaryotes will evolve on their own, once the prokaryotes have reached a more advanced stage of evolution. Often, without interference, eukaryotes appear by 1.5 billion years. On Earth, they appeared approximately three billion years ago, or just about 1.5 billion years after the formation of the planet.

Even though they still wouldn't have appeared for hundreds of millions of years on ancient Earth, in SimEarth let's pick up the pace. So pick Eukaryote from the Place Life list and drop a few of them in different parts of the ocean. You can start doing this as early as 600 to 700 million years. This is very artificial, but we're going for the speed record to the stars, remember? Each Eukaryote will cost you 70 EU. Don't overdo it.

When you try to seed life as you will in the following step, look for a place that isn't too crowded with other life. In general, a more established life form will "swallow up" a less established one. Give the new form room to grow. Once it has started to multiply, it will continue to expand. Place two or three at a time, in three or four different areas that are relatively free of prokaryotes.



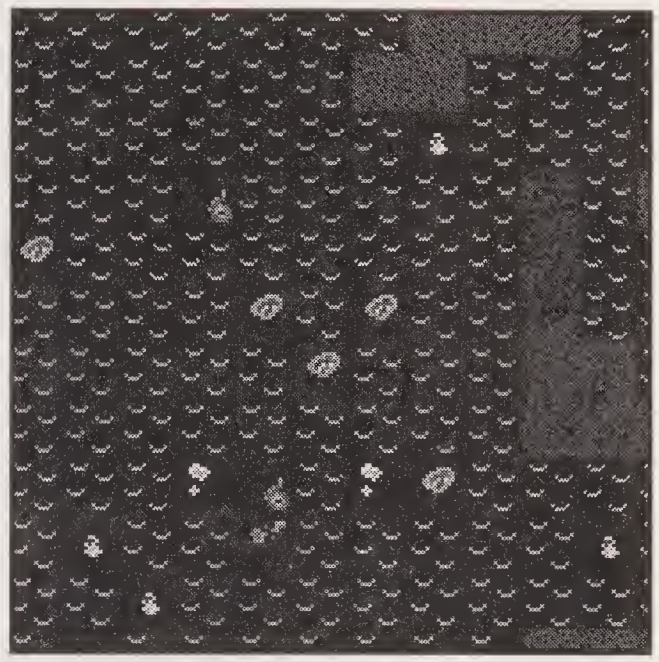
Placing Eukaryotes...

31. Select Eukaryote from the Place Life palette and drop a few in the oceans in the Edit window.

The eukaryotes will appear as a different color or shade in the Map window than the prokaryotes. In the Edit window display, they will start out looking like small, oval cells.

32. If you're still Paused, start again at Slow speed.

At first, the eukaryotes may not seem to do very well. Remember, it's really early for them to be around. However, soon you'll begin to see them multiply.



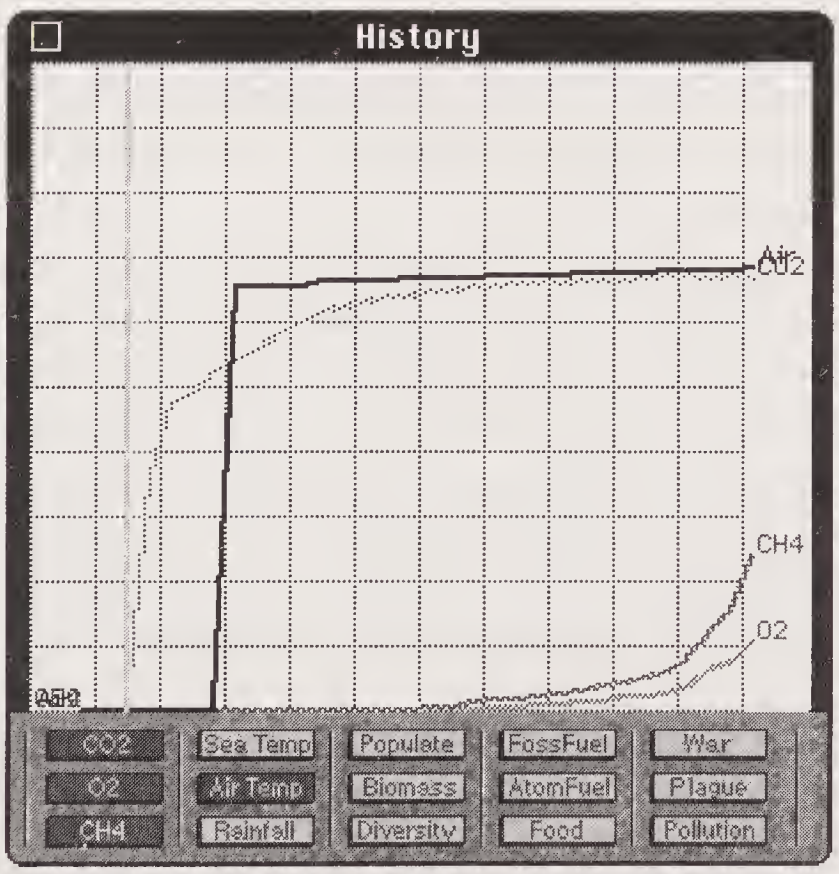
Evolution and growth.

33. Watch the progress of the Eukaryotes in the Map window.

Once the Eukaryotes seem to be doing fairly well at least somewhere on the map, it's time to tamper with nature again. You should see a growing population of eukaryotes in some watery area in the Map window.

34. Before you continue, Pause the game and open the History window.

You can open the History window three ways: from the Windows menu, by double-clicking in the Info box on the Map window, or by using a keyboard shortcut.

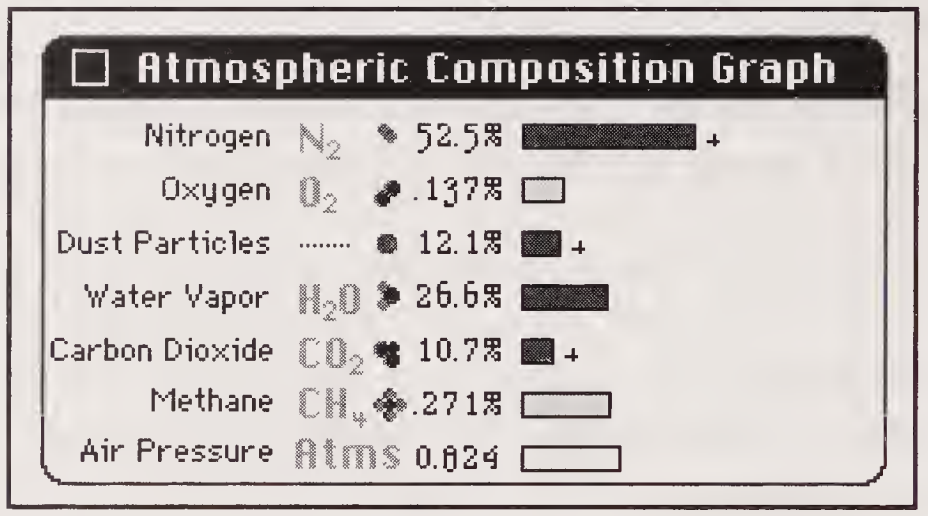


Take a look at the History window. It is, in actuality, a real-time graph window. Clicking on any of the buttons at the bottom causes a graph line to display on the screen. You can follow various parameters in real time on this History window—up to four simultaneously. Right now, you're going to follow four critical components of the atmosphere—CO_2 (carbon dioxide), O_2 (oxygen), CH_4 (methane), and Air Temperature.

35. Click on CO_2, O_2, CH_4, and Air Temp at the bottom of the History window.

You'll see four lines appear in the window.

36. Now open the Air Sample (Atmospheric Composition) graph.

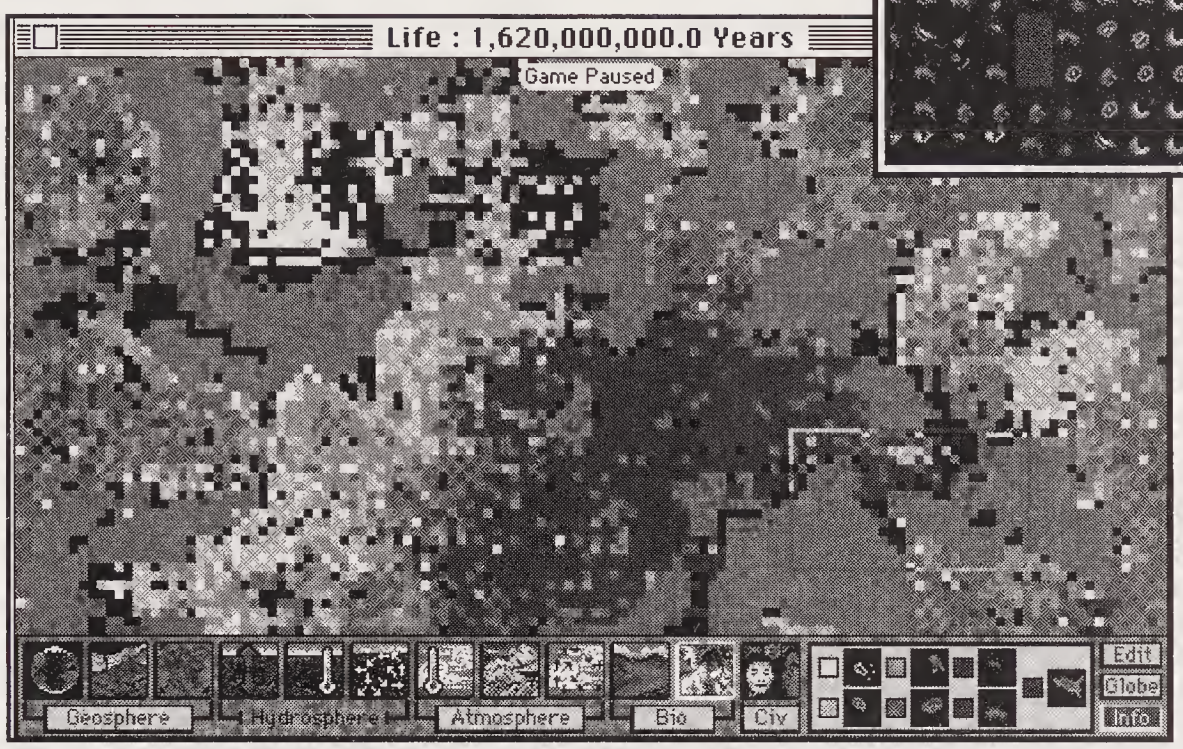


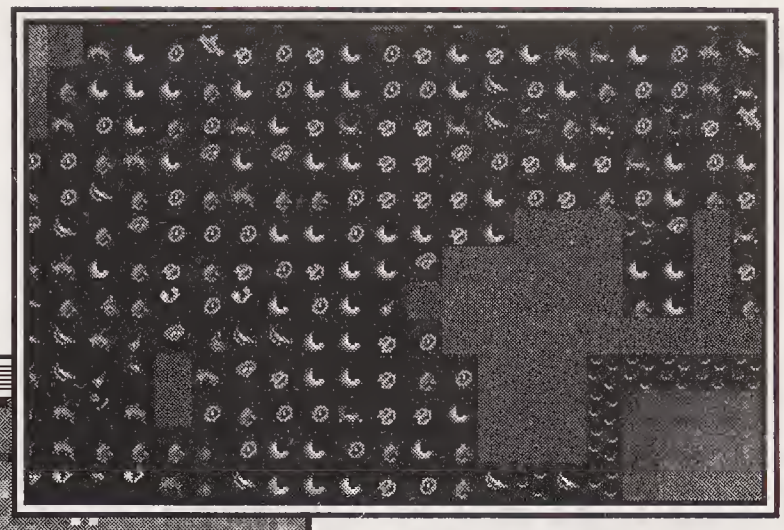
You can open it by selecting Air Sample from the Graphs menu or by double-clicking on the Air Temperature icon at the bottom of the Map window.

Notice that the elements of our atmosphere are represented as percentages in this graph. The color (or, on monochrome systems, the pattern) of a bar indicates its relative volume in the atmosphere. Also, plus or minus signs indicate if the value is currently rising or falling. No symbol means it is in a temporary state of stability.

37. Once again, in the Biosphere Model Control Panel, raise the Reproduction Rate to near the top.

This is a dangerous thing to do. Your oceans will get very crowded. However, now that the oxygen-producing eukaryotes have begun to develop, you can speed up the natural switch to an aerobic world.

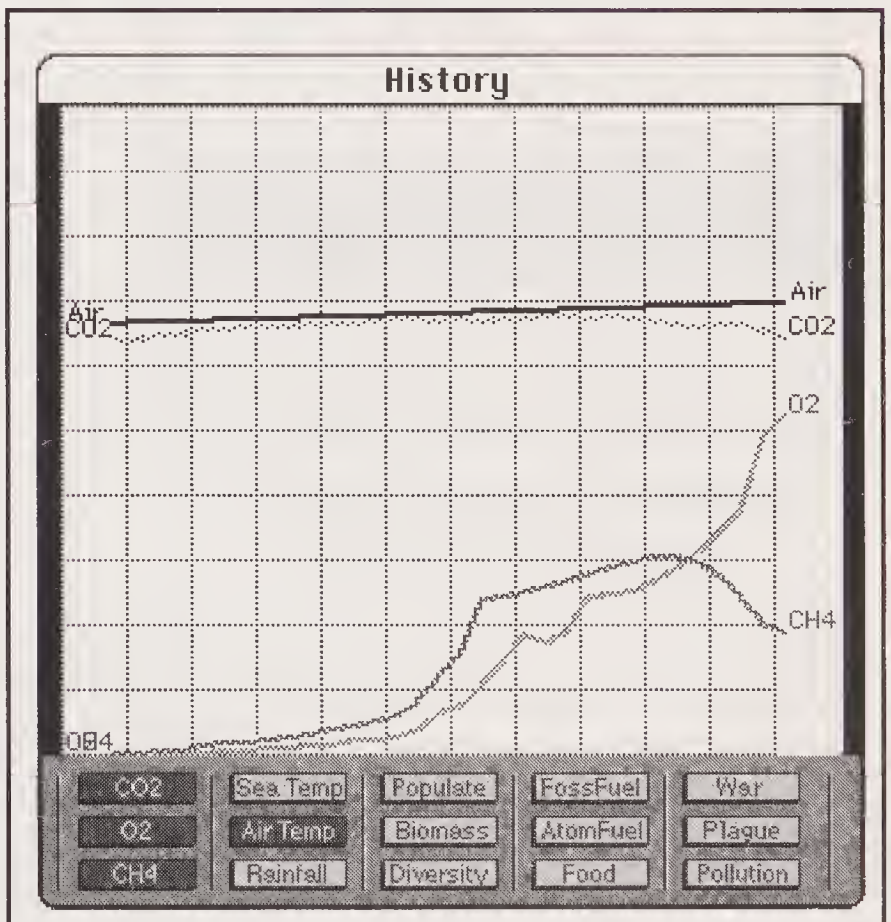




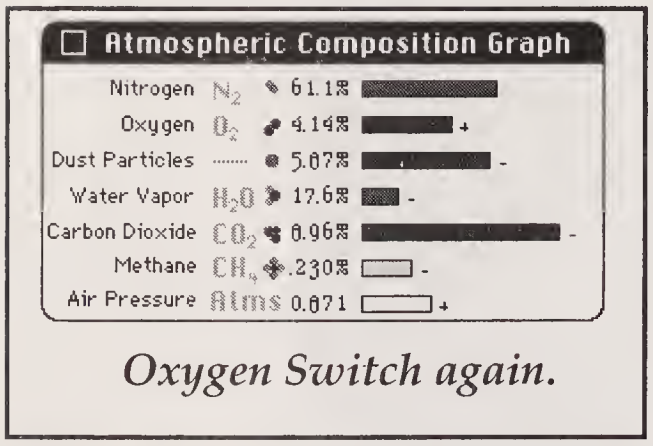
Overpopulation effect of maxed out Reproduction Rate.

38. Restart (unPause) the simulation at the speed you prefer and watch the crucial developments unfold in the Edit, History, and Graph windows.

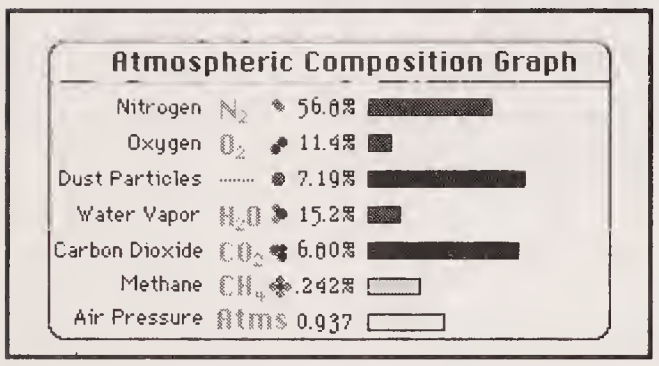
As the eukaryotes proliferate and "discover" photosynthesis, oxygen begins to build up in the atmosphere. Watch it rise slowly, but more or less steadily. At some point, you may notice that CH4 takes a sudden dip and almost immediately, oxygen levels climb quickly. This was a critical moment in the history of life on Earth as the oxygen, a poison for the methane breathers who had populated the planet for so many millennia, now grew to deadly levels. Methane breathers had to find new niches hidden from this poison as their oxygen breathing cousins took over the surface of the planet. The miracle is that the descendants of those original anaerobic organisms still live deep in the muck and dirt as well as in our own guts, places where they are safe from the sure death of

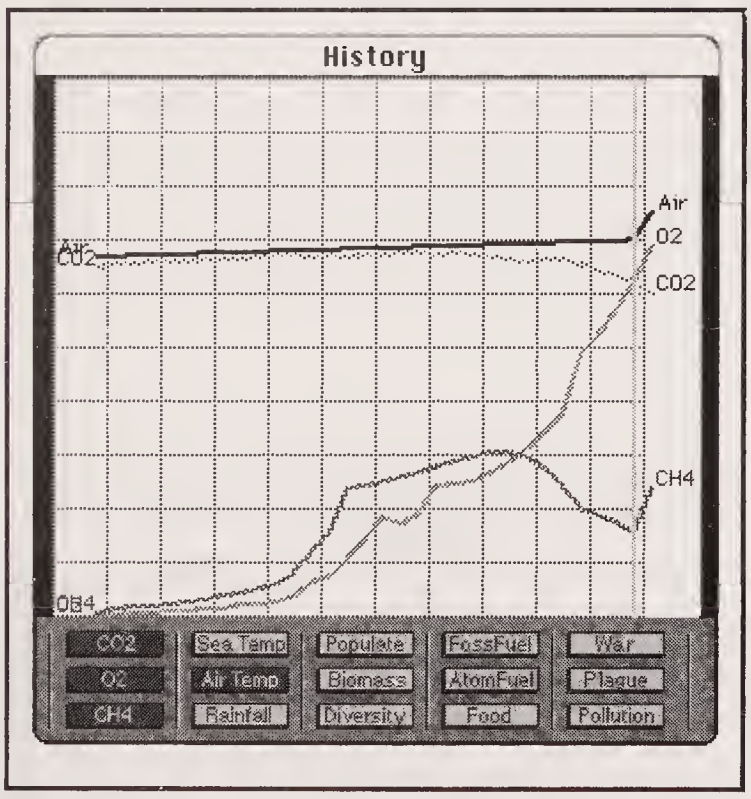


The Oxygen Switch.



Oxygen Switch again.





When the History Graph and the Air Sample look like those above, the planet will usually enter the Evolution Time Scale.

the oxygen-saturated world. Thus the oldest life on Earth still lives there. In fact, it has come with us to visit the stars.

At some point, and this is an arbitrary decision you'll have to make, the population of eukaryotes will be well established and the oxygen levels of the atmosphere will be climbing to around 8 percent or so. Now would be a good time to lower the Reproductive Rate to around the mid-point again. If you leave it high and forget about it, the competition for space will be fierce. Your oceans will become solidly covered with creatures. It is possible to continue the simulation with this high reproduction setting, however.

If you want to experience the results of very high reproduction rates for yourself, save the game now under a new name (say *Tutor2a*) and let the simulation continue without interference.

39 If you get the message that the Evolution Time Scale has begun, lower Reproduction Rate in the Biosphere Model Control Panel to about the mid-point again. Otherwise, when oxygen levels reach about 8 percent, lower Reproduction Rate to the mid-point.

As you watch the oxygen level climb be prepared for yet another revolutionary step.

3 / The Invasion of Land: The Cambrian Period

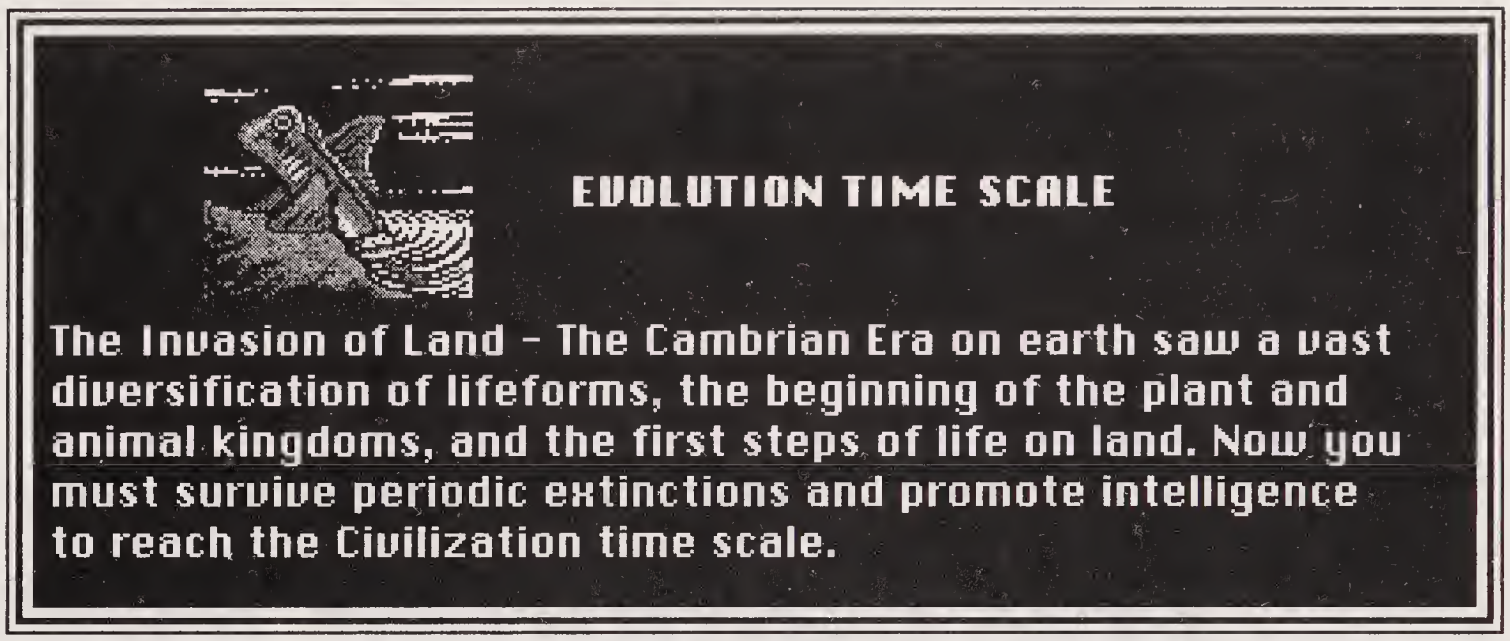
(More Evolution of Life)

Time: 30 minutes
Or: 400–800 million years
Current Goals: Stabilize air temperature, promote life on the planet, watch evolution, reach civilization.

Soon after the oxygen levels in the air reach around 10% (sometimes before), another dramatic change will take place on your planet. If you've been successful (and fortunate) so far, this may be as early as 2.4 billion years (possibly earlier). On Earth, the Cambrian period didn't begin until about 3.9 billion years, and land plants only appeared around 435 million years before Man reached the age of space exploration in the 21st century. So you're doing phenomenally well if you've cut about a billion and a half years off the process!

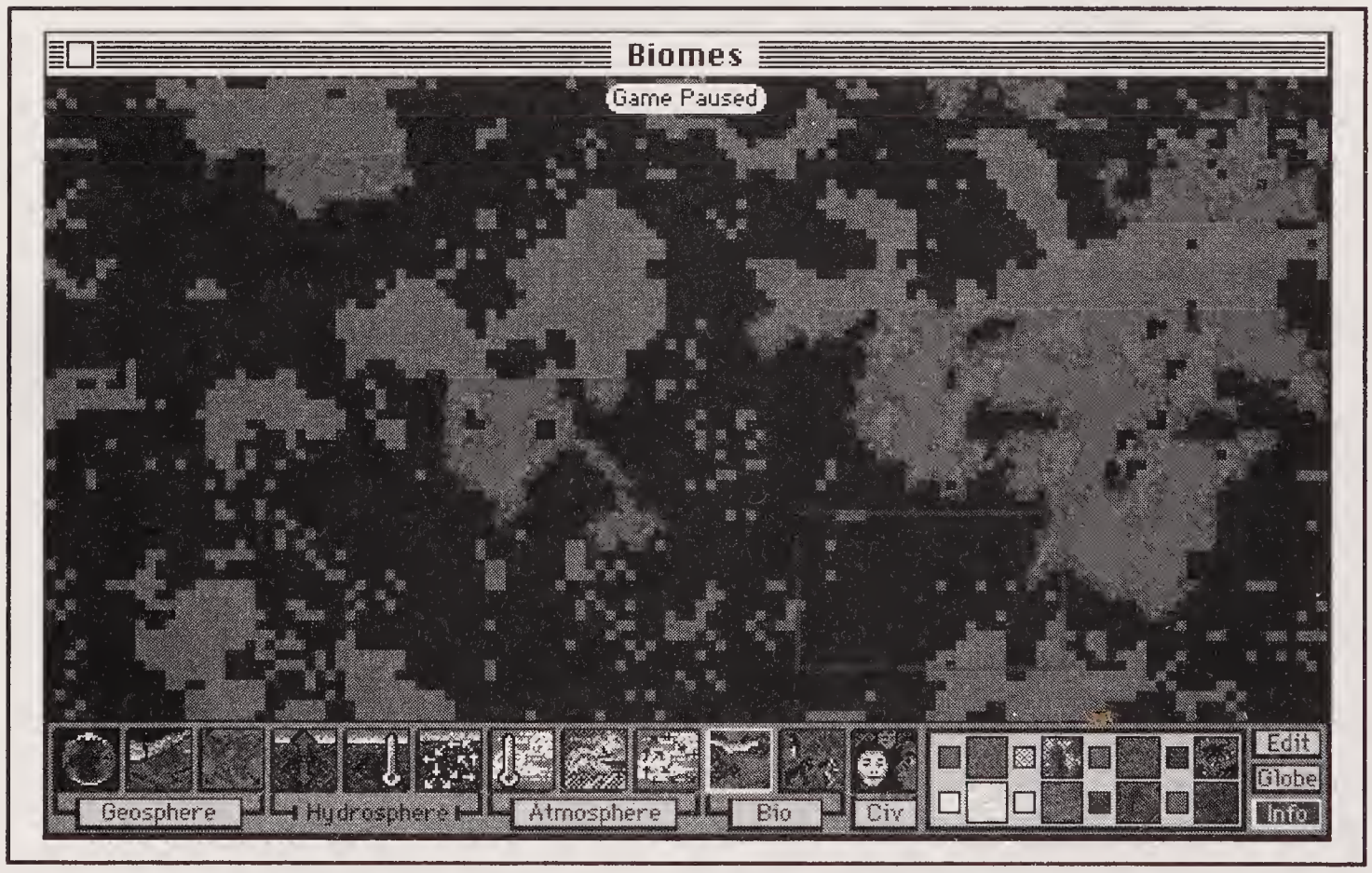
According to the SimEarth time scales, your planet has entered what we call the Evolutionary Time Scale.

Occasionally we've encountered a planet that simply didn't want to enter the Cambrian period. If your planet goes along and oxygen levels continue to rise and perhaps hundreds of millions of years go by, and you still don't reach the Cambrian, you may have what we at G.O.D.S. affectionately refer to as a "dud" planet. Best to go back to your last saved planet and start from there again. It will probably work just fine the next time.



1. As soon as the program informs you that the Cambrian period has begun, Pause the planet.

2. Click on the Biomes icon in the Biosphere group (the first icon under the Bio label).



Methane is no longer a major atmospheric gas, and generally won't play a large role in the climate patterns of your planet from this time on. It is a powerful greenhouse gas, however, so if its levels rise, they can affect the planetary warming.

However, a more important aspect of the climate to track at this point is rainfall.

3. **In the History window, click once on CH4 to disable the methane graph, and click once on Rainfall so you can track the general wetness of your planet.**

   Small fluctuations in rainfall can have significant effects on the biomes on your planet. You'll see how this can work later.

4. **Now use Save As to save the game as *Tutor3*.**

Activating the Biomes icon lets you watch the spread of plant life over land. You'll notice that time now passes much more slowly in the simulation. Each "tick" is now only worth 250,000 years instead of 750 million!

5. **Restart (unPause) the planet at Slow speed.**

Very soon, the first multicellular life will evolve—the radiates. At about the same time, the plant life invasion of land will be in full swing and a profound change will begin to take place on your planet. Now is a time for you to make a very important decision.

6. **Once radiates evolve, Pause again and read on.**

Important SimEarth Note: *You may have noticed that suddenly a lot of land disappeared. This is not really*

because the radiates appeared and made rain or something. It is another artifact of the computer. Fortunately, if you follow the instructions that follow, you won't need too much land area. Still, you should have some. Volcanic activity and continental drift will still form new land, so even if there isn't much on your planet now, there may be more in a few tens of millions of years.

Another Important SimEarth Note: *Events are going to happen quickly now, even though the time scale is reduced. The climatic changes are accelerating. The first thing you'll notice, if you watch the History graph, is that the Air Temperature begins to rise. This is, unfortunately, due to how the modeling works and not an effect we would expect to happen in the natural evolution of the planet. In other words, like the disappearance of land when radiates appear, it is a bug in the SimEarth toolkit.*

Even though the temperature increases at the beginning of the Cambrian period, and the oxygen level also increases, carbon dioxide will soon begin to fall rapidly as the plants scrub CO_2 from the air at an increasing rate. So even though the air temperature is beginning to get quite warm, it would be a mistake to react only to that trend right now. Because very soon, with CO_2 levels approaching their minimums, the greenhouse effect will be so low that the planet will cool and enter an ice age.

Ice ages are natural, and life on your planet will survive and even evolve, but you may want to attempt to stabilize the situation. As far as SimEarth is concerned, biomass (the total biological matter on the planet) is desirable, and the warmer climate seems to promote greater amounts of biomass. There are some who would suggest that such periods of warmth are exceptional, and that Gaia is at her most healthy during the long ice ages that seem to occur with great regularity.

However, SimEarth seems to thrive in conditions like those that occurred during the age of the dinosaurs, which was incredibly hot, "feverish" as Dr. James Lovelock describes it. Therefore, while you can allow ice ages to proceed normally, you can also interfere and create an artificially hot world using the various tools at your command.

Keeping your planet warm and stable can be tricky, but it is possible. Your main tools are going to be found in the Biosphere Model Control Panel and the Atmosphere Model Control Panel. Depending on your strategy, you may use a combination of factors, including Solar Input, Cloud Albedo, Surface Albedo, Rainfall, Greenhouse Effect, and CO_2 Absorption. You can also control CO_2 levels using Erosion (found in the Geologic Model Control Panel).

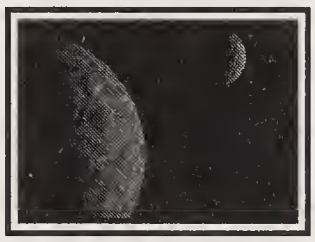
Our preferred method of interference is to use a combination of CO_2 Absorption and Greenhouse Effect. In the current situation, even though the planet is starting to overheat, CO_2, a major greenhouse gas, will soon begin to fall as the new plant life "breathes" it in. The real problem lies there. To fix it, try decreasing the amount of CO_2 absorption of the new biomes.

You may find that the stabilization of the planetary temperature is difficult. Don't worry. You may have to try it more than once. If your planet overheats, you'll get messages about mass extinctions occurring or oceans boiling over, or you may just see a lot of hurricanes. Some of these situations are pretty serious. That's why you saved the game at the beginning of the Cambrian period. Remember, you can choose Load Planet and select Tutor3 *any time to try again if your first attempts aren't successful. We'll offer lots more hints as you read along in this chapter.*

7. Still Paused, switch to the Biosphere Model Control Panel, and select CO_2 Absorption.

8. Nudge the absorption level from its current level (about halfway) down to about the first large tick mark.

To nudge, click just below the slider.

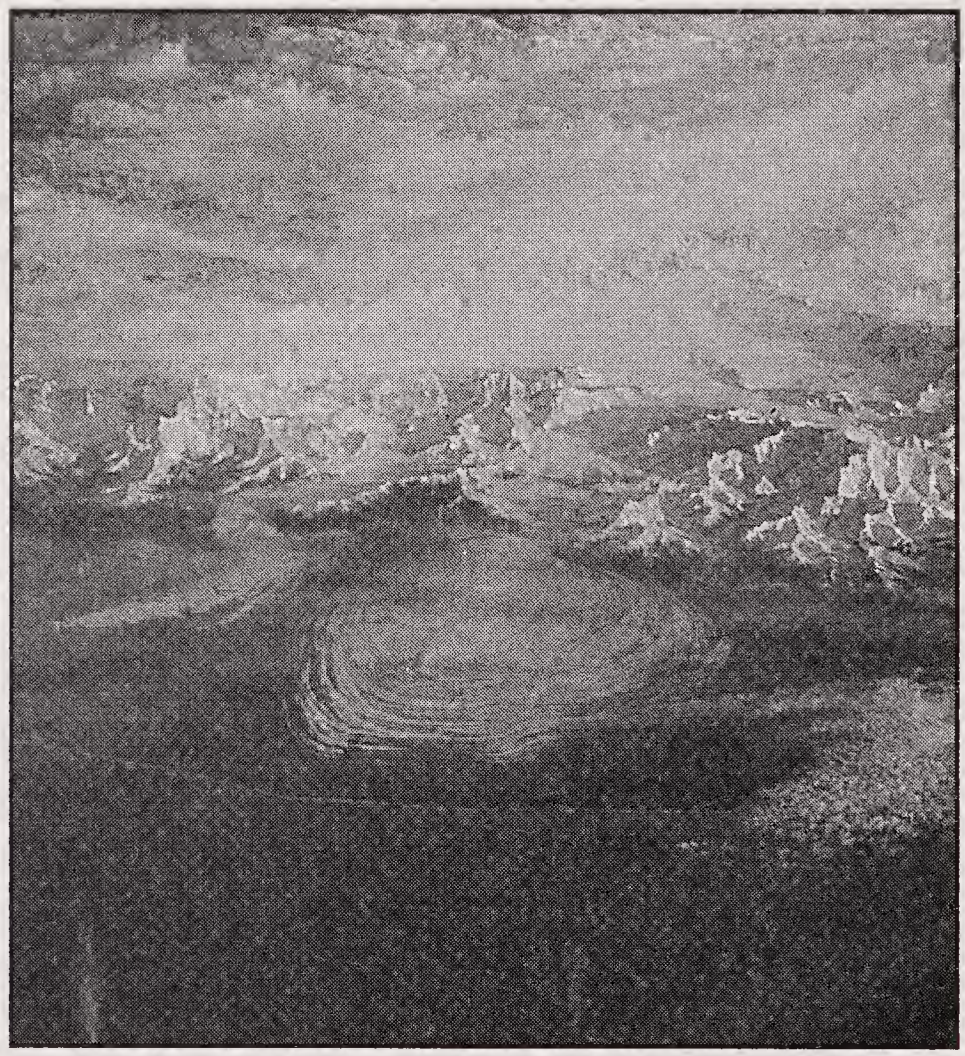


About Ice Ages

Everybody has heard of ice ages. For a long time we believed that ice ages killed the dinosaurs, but that theory is now in doubt with theories ranging from catastrophic meteor impacts to deadly constipation as possible causes of the dinosaurs' demise. However, whether ice ages caused the end of the dinosaurs' 65 million year reign on Earth or not, there is no doubt that ice ages do occur.

Scientists have wondered about ice ages for quite some time, but it is only in the past few decades that they have been able to decipher the clues left in the Earth's strata and come up with convincing evidence to explain the ice cycles.

Ice ages are caused when abnormally cold winters follow one after another. As snow and ice build up and less and less melts during summer, not only does the ice spread into the lower latitudes, but the very existence of the increased ice tends to cool the planet more since the albedo of ice is very high, meaning it reflects more sunlight than just about any other natural surface. As less sunlight warms the Earth, of course the ice spreads even more.

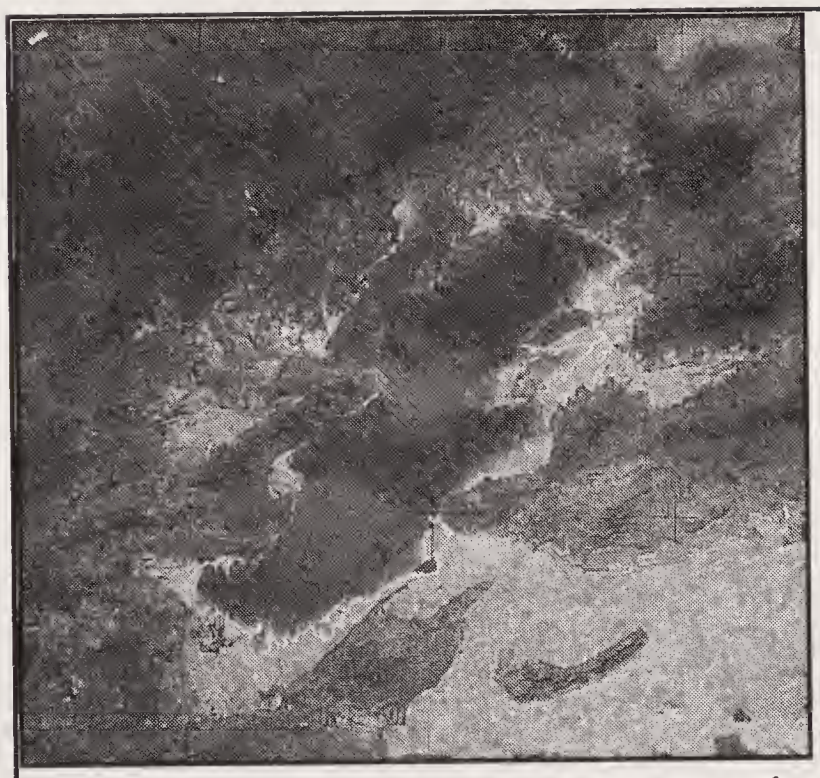


The Malasipina Glacier in Alaska. Concentric semi-circles are moraines associated with glacial surges.

But the mystery of the ice age cycles, which eluded scientists for so long, has now been solved. The cause, it seems, is the very periodic fluctuation of the Earth's rotation and axial tilt. Over long geological cycles, the Earth's orbit around the sun changes due to the effects of gravitational forces from other planets. In addition, the tilt of the Earth wobbles regularly. For instance, the North Pole currently points at what we call the North Star, Polaris. 2000 years ago, during the time of Julius Caesar, it pointed somewhere between the Little Dipper and the Big Dipper. The result of these and other various fluctuations in the Earth's journey around the Sun seems to cause regular periods of colder weather which we call ice ages.

Based on extensive study, scientists have determined that ice ages occur according to a fairly regular set of cycles. Over the past 500,000 years, scientists have discovered ice age cycles of 100,000, 43,000, 24,000, and 19,500 years.

The last major ice age ended about 18,000 years ago, and it was a big one in which all the major cycles coincided. In the 17th century, however, there was what the scientists



The Great Salt Lake is a remnant of Lake Bonneville, formed during the last great Ice Age.

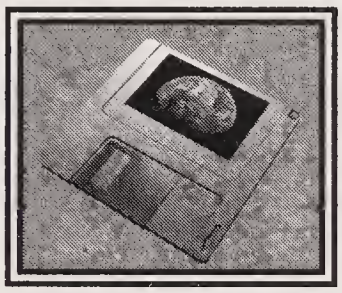
are calling a Little Ice Age, a period of unusually cold winters. This climate event was left for us to discover in the geological records, but was even more obviously recorded in some of the famous paintings of the day by such masters as Rembrandt van Rijn, Frans Hals, and Jan Vermeer, all of whom painted scenes of ice and cold that were once considered cases of artistic license, but now are considered to have been based on the results of an ice age, however mild.

If the theories are correct, we are in the middle of a very unusual hot period in Earth's history, and another ice age should begin within the next few thousand years. In fact, some think a mini-ice age like the one that occurred during Vermeer's time might occur again in the next century. The next major ice age, still probably several thousand years away, shouldn't be as intense as the one that ended 18,000 years ago. Still, this period of warmth we now enjoy is unusual. According to one scientist, temperate climate like that of today's Earth has only accounted for about ten percent of the past million years.

In *The Ages of Gaia,* James Lovelock goes even further and suggests that ice ages are the normal state of the Earth and periods of warmth are anomalies.

"Geophysiology suggests that, to regulate the climate in the face of increasing heat from the Sun, glacials are the normal state and interglacials, like now, are the pathological ones." Lovelock further suggests that, as the weather turns colder and the ice caps grow, water levels may fall, "exposing vast areas of rich and fertile soil on the continental shelves... It could have covered an area comparable with that of Africa now, and could have supported tropical forests."

Long Island and Cape Cod are examples of eroded glacial terminal moraines deposited during the last great ice sheet advance into North America. Marine currents have reshaped them over time.



Using the Model Controls

- **Solar Input** simply increases or decreases the amount of energy the planet receives from the Sun. Push the slider up to make things hotter. Push it down to cool things off.
- **Cloud Albedo** affects how much sunlight (and heat) reaches the surface of the planet. The higher the albedo level, the more light is reflected back into space. Therefore, raising the Cloud Albedo setting should have a cooling effect on the planet.
- **Surface Albedo** affects the reflectivity of the ground. Obviously, large areas of ice and snow will have a high albedo and will reflect more sunlight than forests or jungles. Deserts, too, have a high albedo. Using this model setting you can change the overall albedo of the planet's surface without actually changing the biome distribution.
- The **Rainfall** setting obviously affects the overall amount of rain that falls globally. It can't affect any specific area, but it will cause a shift in the biome distribution. For instance, if you have large areas of swamps and you want more tropical rainforests, raising the Rainfall setting a little might do the trick.
- The **Greenhouse Effect** controls how much heat is trapped in the atmosphere and re-radiated back to the planet. Gases like carbon dioxide and methane are powerful greenhouse gases, and a planet can overheat if the greenhouse effect becomes too heavy. By manipulating the strength of the greenhouse effect in the Atmosphere Model Control Panel, you can do what today's scientists wish they could do, raise or lower the intensity of the greenhouse effect and thereby control the temperature of the planet.
- The **CO_2 Absorption** level found in the Biosphere Model Control Panel regulates how much carbon dioxide plants and other photosynthetic organisms will take out of the atmosphere. If carbon dioxide levels are increasing, raising this slider will effectively scrub out excess carbon dioxide, but be careful. Taking too much CO_2 from the atmosphere can result in planetary cooling and also in the formation of desert regions as plants become starved for the necessary carbon dioxide they breathe.

  If you want to increase the level of CO_2 in the atmosphere, you can raise the Erosion setting found on the Geosphere Model Control Panel. This also tends to smooth off your continents, so you may lose some land in the process. In general, however, you shouldn't have to mess around with Erosion rates.

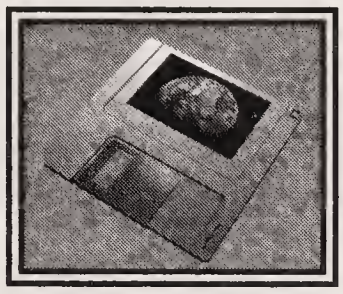
The amount you will change the model controls in these next few steps may depend to some degree on how much land there is on your planet. A good rule of thumb is that if you have very little land, you need to make larger changes to the models. With lots of land (and therefore lots of plant life), changes should be kept very subtle.

NOTE: *In the section that follows, you'll have two problems to deal with. One is the temperature of the planet. The other is the amount of energy (EU) you have left. You may not realize it yet, but very soon (geologically and in game time) one of the species on your planet will achieve sentience and then you'll have to take care of a fledgling civilization. You'll need considerable energy early in that process, so be careful what you do in this beginning part of the Paleozoic age.*

9. **(Optional) You may want to switch to the Atmosphere Model and select the Greenhouse Effect. Nudge its value down about one notch to bring the planet's temperature down.**

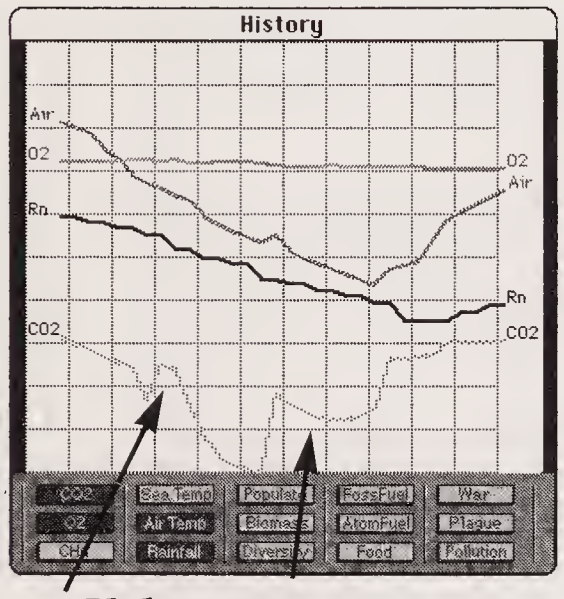
   Sometimes lowering the greenhouse effect one notch is very effective. Other times it isn't enough. You'll have to experiment with your planet to find the right amount of adjustment your model controls need. Eventually, with lowered greenhouse effect and falling CO_2, air temperatures will begin to fall.

10. **Start the game again at whatever speed you find comfortable, but watch the falling CO_2. Eventually Air Temperature will begin to fall, and if it seems that the Air Temperature is going to keep falling, raise the Greenhouse Effect back to where it was.**



Using the History Window to Follow Climate Changes

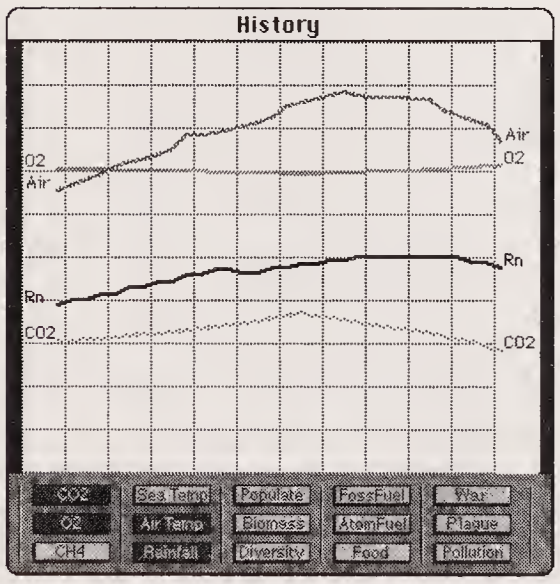
In this section, the three History windows on the left are sequential. They show the climate changes that might happen during the Cambrian period and how to counter their effects. On the right are two History windows that represent unstable, ice age conditions.



Volcanoes

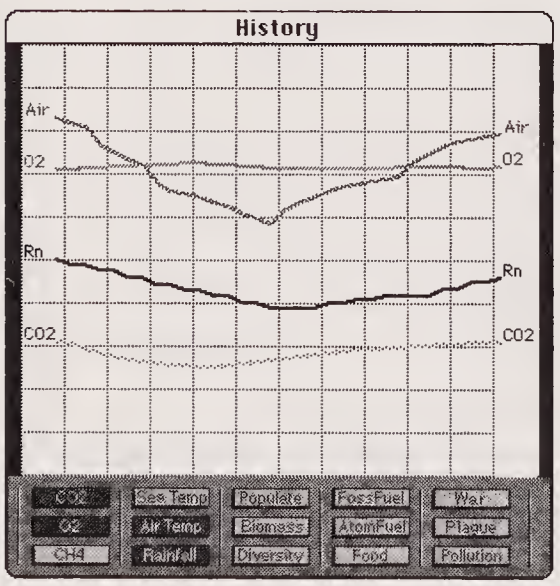
History 1

- *Dropped CO_2 Absorption at the start.*
- *With Air Temp. still falling, nudged Greenhouse Effect.*
- *As CO_2 bottoms out, nudge down CO_2 Absorption and raise Greenhouse Effect.*
- *Watch the oxygen levels and see how CO_2 rises and Air Temp. rises and steadies.*



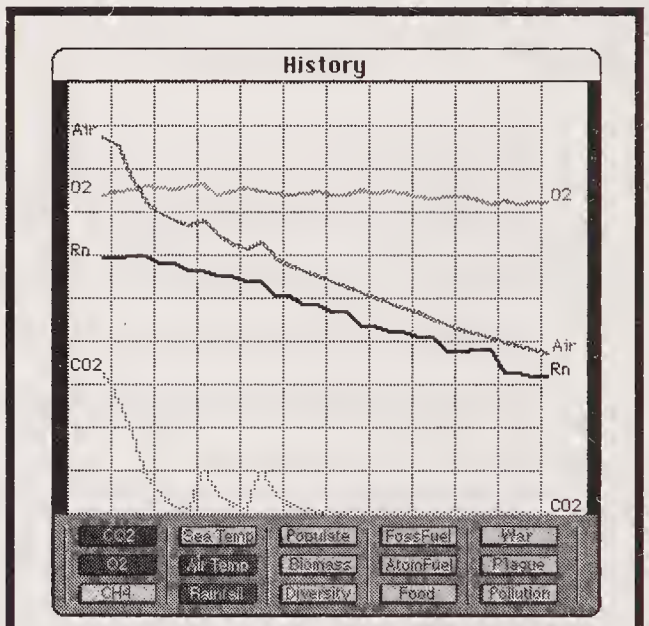
History 2

- *With Air Temp. rising, drop Greenhouse Effect and bump up CO_2 Absorption.*

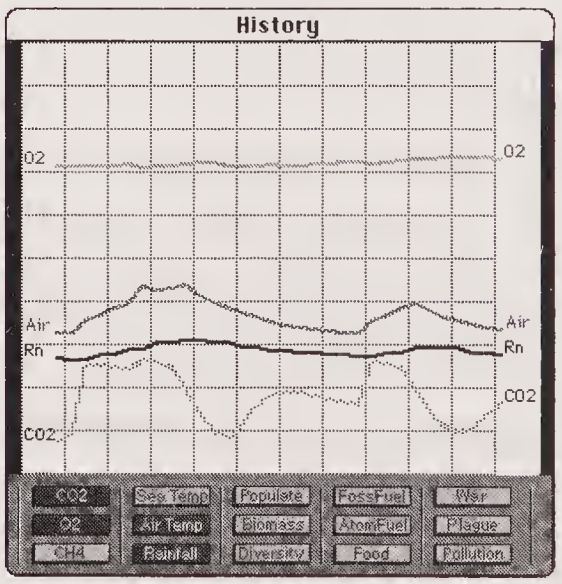


History 3

- *As Air Temp. falls again, bump up Greenhouse Effect once or twice.*
- *By now the Radiates are at or near 90 IQ and CO_2 is stabilizing.*



Two ice age models.



One way to tell if CO_2 is falling is by the steepness of the graph line in the History window. If the line is angling down steeply, chances are it will continue to go down. Careful adjustments in the model windows can flatten the angle of the graph and counter the unwanted trend.

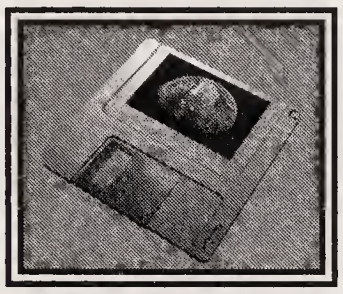
11. When CO_2 levels begin to rise again, Pause and read the next sections.

Another way to increase CO_2 levels, at least temporarily, on a planet with very little land is to set off a few volcanic eruptions. However the greenhouse effect of volcanic action is short-lived. Also, volcanoes send dust into the air which can block sunlight and have the opposite effect. On a planet with very little land, however, this is a pretty good time to create some new continents or expand the old ones with some well-timed volcanoes.

If your timing was good with the CO_2 Absorption and the Greenhouse Effect, the air temperature should eventually reach a relatively stable point, perhaps still experiencing slow, gentle, flat swings. If you're experiencing wild swings in temperature and carbon dioxide levels, then you need to make careful adjustments. Try waiting until a CO_2 swing is on its way back up and raise CO_2 Absorption levels just a little to counter it. Eventually, you should reach stability. If not, your planet will experience periodic ice ages until it stabilizes itself.

If you can't stabilize air temperature, you may want to restart *Tutor3* and try again. With a little practice, you'll get the knack.

Another effect to observe is the rising oxygen level. If you don't allow the plants to scrub out CO_2, you could even cause a problem with oxygen levels staying too low. So be aware of your oxygen levels when you have CO_2 Absorption set very low. Oxygen levels should continue to rise until they reach about 21%. At that point, Gaia will regulate oxygen fairly well. If the level begins to rise past that point, fires will break out, consuming excess oxygen and releasing more carbon into the air. Oxygen levels should remain fairly stable, but if you



Climate Adjustment Tips

This is probably the trickiest period of planetary development. Stabilizing the climate can be very difficult. What it requires most of all is a sense of timing and a sort of instinct for how much to change the model control panel settings. Sometimes small movements can create immediate effects. Other times, you may want to move one of the settings several notches at a time to counter an unwanted trend, then move them back when the opposite effect has started. Here's a general guide to what to do during this period.

If Air Temperature is rising and the planet is overheating:

- Lower Greenhouse Effect
- Raise CO_2 Absorption
- Lower Solar Input
- Raise Cloud and Surface Albedo

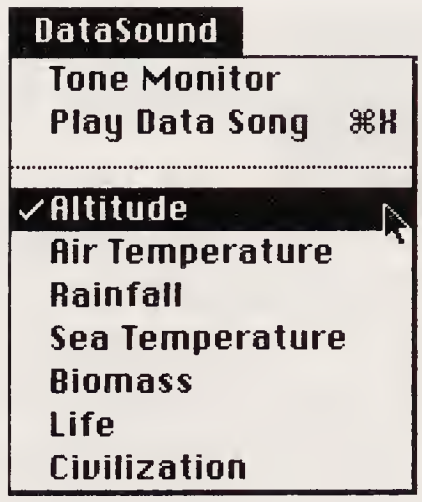
If Air Temperature is falling and the planet is freezing:

- Raise Greenhouse Effect
- Lower CO_2 Absorption
- Raise Solar Input
- Lower Cloud and Surface Albedo

We generally use a combination of greenhouse effect and CO_2 absorption to control the climate. It's a little like tuning a musical instrument. Knowing just how much to move the sliders takes some practice, but eventually you get a feel for it. That's why you saved the planet at the beginning of the Evolution Time Scale—so you can practice.

see any consistent trend downward, you may want to pay additional attention to the carbon dioxide cycle.

Although you may choose to pay close attention to the temperature and CO_2 cycle of your planet, you may also want to keep an eye on some other factors. Remember the Report window you looked at millions of years ago, right after the oceans formed? In a moment you'll look at it again. You may want to enter Pause mode at this point, but it isn't absolutely necessary. You can continue to monitor the air temperature (or any of seven other factors in the game) by using your ears instead of your eyes.



12. Open the DataSound menu and look at the options there.

13. Select Air Temperature.

This is another SimEarth tool that lets you monitor the sound of the air temperature as it rises and falls.

14. Now, and this is just for fun, select Play Data Song from the DataSound menu.

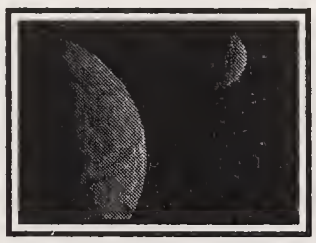
You'll hear a little tune that's actually based on the air temperatures at different parts of the planet, moving from the northern pole to the southern pole. The higher the tone, the higher the temperature (so obviously, the tones are lower at the poles and higher at the equator).

15. A more useful option is to choose Tone Monitor from the DataSound menu.

The Tone Monitor plays a sound every so often. In this case the sound indicates the average planetary air temperature. This is essentially the same information you receive in the History window from the Air Temperature graph. Choosing another option from the DataSound menu would monitor another aspect of the planet.

As you work, you'll hear that tone to remind you of the air temperature, and if you hear it rise or fall, you'll know that the stability of your planet is threatened and it's time to take some action. Meanwhile, you can proceed with your other work.

Now you're free to examine some of the other resources available in the SimEarth toolkit.



Deserts in SimEarth

Star dune patterns in the Algerian desert as seen from space.

One of the interesting facts of Gaia's self-regulation is approximated rather well in SimEarth. Deserts are a natural result of certain factors. On a local scale, deserts might be caused by abnormally low rainfall, but on a global scale, as in SimEarth, you will notice that deserts grow because of other effects as well. For instance, as a planet heats up, desert areas tend to grow. The temperature is simply too hot to support other biomes. Check the legend in the Info Box section of the Map window to recognize deserts on your system.

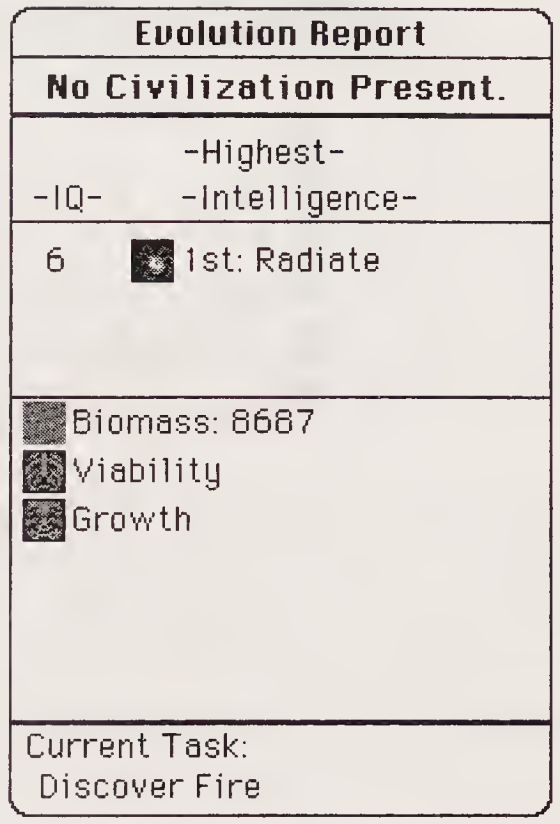
Deserts may help counter the effect of overheating in certain ways. Though they scrub less carbon dioxide from the atmosphere, they do have a higher albedo than most dense green biomes, and therefore will reflect more heat back from the ground. And there is less oxygen-breathing, carbon dioxide-exhaling life in the desert than in most biomes. And deserts are dry. They don't release much water vapor into the air, and water in the air acts as a greenhouse gas as well.

Deserts will form on the opposite side of the scale as well—when there is too little CO_2 to support enough green plants. Here, the effect of the desert is relatively straightforward. By producing less CO_2-absorbing biomass, the levels of CO_2 are allowed to increase. You'll see that if CO_2 levels fall low enough in SimEarth, even if the temperature is very cold (which it probably will be), deserts will form. As CO_2 levels rise again, the deserts will once again give way to greener biomes.

16. Open the Report window.

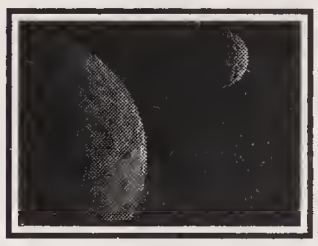
Last time it was called the Geologic Report. The report is now called the Evolution Report and, where the former task was to evolve multicellular life, now the Current Task is to discover fire.

In addition to the information about Biomass, Viability, and Growth, there is an interesting new section that shows the development of intelligence in multicellular life. In all probability radiates are already registering some intelligence. If not, they soon will. As life forms evolve, they will increase in intelligence. Eventually, one will achieve sentience and civilization will begin. Using the Evolution Report window, you can see who is in the lead to take this great step.



Another window to check at this time is the Biome Ratio Graph.

17. Open Biomes from the Graphs menu or double-click the Biome icon in the Map window.



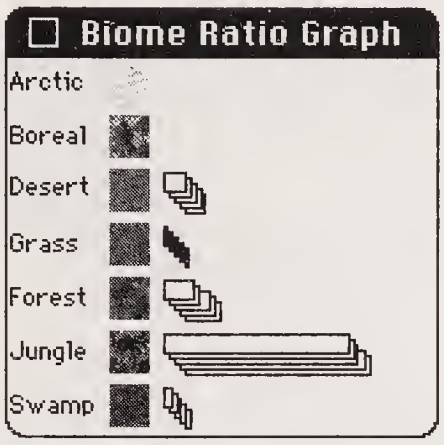
CO_2 and the Carbon Cycle

Carbon is the building block of life. In fact, the intimacy of carbon to life is emphasized by the fact that any compound containing carbon is called "organic." Carbon moves through the life of Gaia in many ways. The most commonly known method is through the respiration of plants and animals.

It is generally understood that plants "breathe" carbon dioxide and release oxygen as a byproduct while animals breathe oxygen and release carbon dioxide. This amazing symbiosis between the plant and animal world is one of the stabilizing factors in the world. However, it is not the only aspect of the carbon cycle. Great amounts of carbon are stored in biomass (trees, etc.) and buried in limestones formed from the bodies of organisms that make their shells from calcium carbonate. During the early development of the Earth, the depositing of this carbon in the sea floor allowed more free oxygen to accumulate which was an important factor in the switch from an anaerobic atmosphere to an aerobic one. Basically, for each carbon molecule buried in the sea floor, two oxygen atoms were freed.

Buried carbon can return to circulation in the atmosphere by erosion or by volcanic activity which can melt down the limestone and other rock, releasing carbon dioxide gas.

The carbon cycle is critical to the maintenance of the health of the planet, and it is further indication of Gaia's subtle regulation that so much of it is absorbed by sea creatures and later buried and taken out of circulation. Obviously the balance thus maintained has been beneficial for life for billions of years.



The Biome Ratio graph will show you the relative distribution of biomes on your planet. It's a good way to keep track of the biological health of your world. In addition, you may be favoring a particular species and wish to find out what biomes are best for them. By checking the Biome Ratio Graph, you can determine if suitable conditions exist in sufficient quantity to help your favorite species thrive.

To read the biome ratio graph, look at the size of the bars. The larger the bar, the more of that biome there is. Also, the front bar represents the most current reading. The bars behind it represent the four previous values.

How do you tell what biomes a species favors? One good way is to use the Examine icon (the magnifying glass found on the Edit window palette).

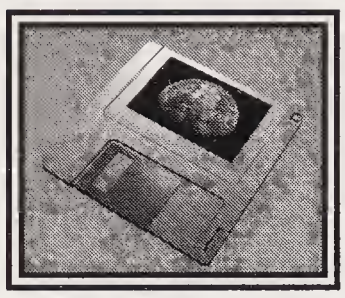
18. Switch to the Edit window and select the Examine icon (if it isn't already selected).

Notice that it only costs 5 EU. You can also use the Help feature (click on something with the Shift key held down), but its cost may vary. The Examine tool is a safer choice for examining the display area in detail.

19. Now place the Magnifying Glass cursor over a creature in the ocean.

(If you don't see any creatures in your Edit window, click on the Life button in the Edit window palette to view the creatures there.)

You'll notice a lot of information about that creature, including which biomes it favors. You may notice that radiates only thrive in oceans and in swamps. Later, other life will evolve that is more suited to land ecosystems.



The Evolution of Life Forms—SimEarth Style

Each life form in SimEarth evolves through 16 classes of increasing intelligence. This evolution is affected by several factors, including the Advance Rate and Mutation Rate (which can be set in the Biosphere Model Control Panel). In addition, SimEarth takes into account the location of the life form. If it is in a very beneficial biome, it will evolve more rapidly than if it is inhabiting an area of marginal value to the species.

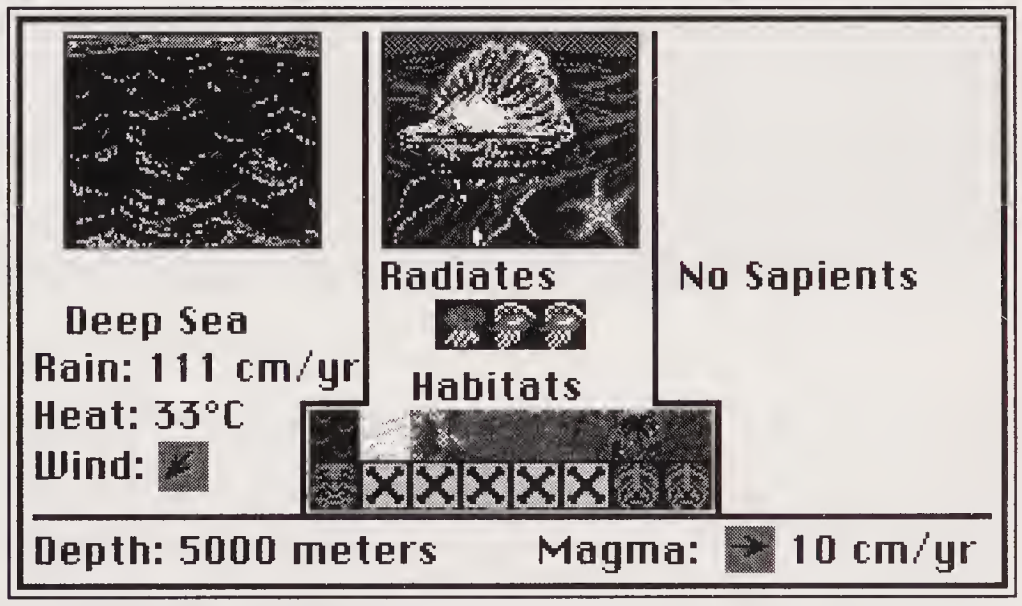
There is also competition taking place on the planet. In general, a life form higher on the evolutionary scale will "take over" one lower on the scale if they happen to meet. On the other hand, a more advanced form of lower life may defeat an early example of a higher life form. As an example, a level 8 dinosaur would defeat a level 2 mammal. In fact, a level 12 insect might also defeat a level 2 mammal, even though mammals are much higher in the evolutionary ladder. On the other hand a level 4 mammal would defeat a level 4 insect or dinosaur.

Once a life form reaches the sixteenth level of evolution, it is considered intelligent. However, to achieve sentience, it also has to be on land (to discover fire), and its current biome may also influence the probability of starting a civilization.

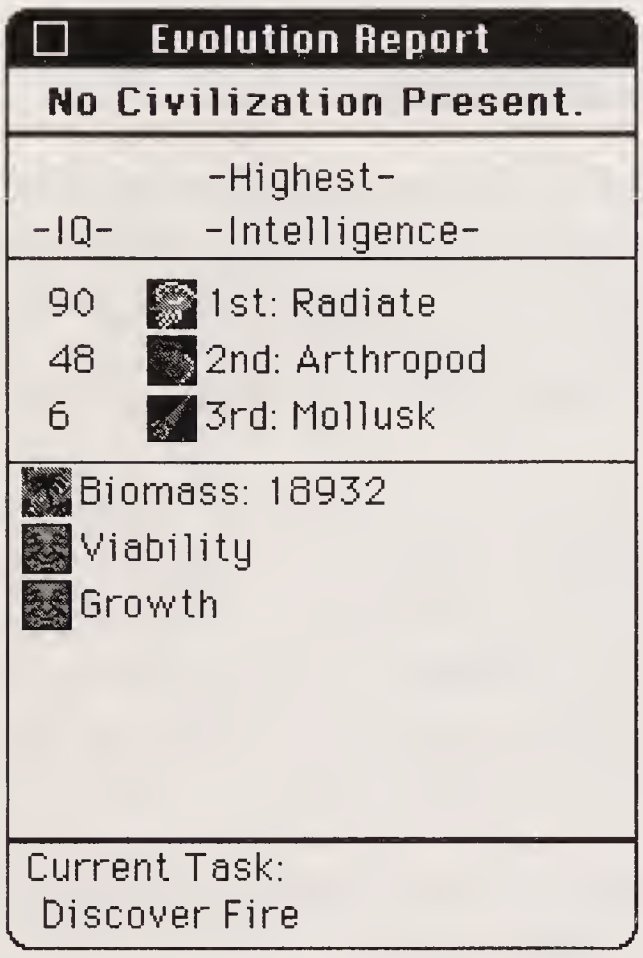
One useful trick with the Magnifying Glass is to click once and hold down, then scroll around over the Edit window, reading information about many different creatures and biomes. If you only click once and scroll around, it only costs you 5 EU. If you click, then release, then click again elsewhere, you pay for each click.

20. If you Paused the game to follow these last few steps, start the planet going again and watch.

If you can keep the environment beneficial to life, new species will continue to evolve. First arthropods, then tricords should appear. Watch the biomass level in the Evolution Report window. It gives you a pretty good idea how inviting your planet is to life.



The Examine window.



You're waiting for one of your creatures to reach civilization. But how will they do that? Well, their task, as the Report window says, is to discover fire. They can't do that in the oceans, so they'll have to get onto land to move to the next step. For the purposes of this planet, we want the radiates to make it to civilization, and they should eventually reach 90 IQ, meaning they're ready to make the move. However, they can only live in swamps or in water. Therefore, to make their job easier, you may want to make sure there's some swampy land on your planet.

Swamps develop in hot, wet places, so that's the kind of atmosphere you'll need. However, if you study the biome charts on page 136, you'll find that certain minor differences in rainfall or temperature can affect biomes. On most hot planets, there are large areas of tropical rainforest. However, with a little less rainfall, those tropical rainforests will turn to swamps.

21. Look at the Map window and try to find some swamps.

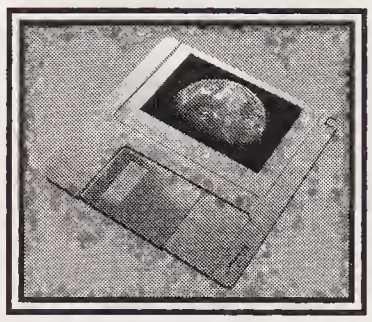
You may need to check the legend in the Info Box to tell which areas are swamps.

22. If your planet has no swamps, try increasing the temperature or perhaps reducing the rainfall by using the Model Control Panel tools.

Swamps can change quickly into rainforests or grasslands if climate conditions change, so once you get some swamps, try to keep the climate stable. Then you wait for some smarter-than-average radiate to stumble on the secret of fire in some murky swamp. It may sound unlikely, but it happens.

Ultimate SimEarth Secret: *Actually, we have discovered in our travels that some radiates will actually reach sentience on land other than swamps. Our best guess is that they were just visiting friends when they stumbled on the secret of fire. At any rate, what this means is that it isn't absolutely necessary to have lots of swamps for radiates to become sentient, but it does help.*

Now read on in Chapter 4 to prepare the way for civilization. You should have some time, so leave the planet evolving. But if your radiates are especially clever and reach sentience before you finish reading the following sections, Pause until you're ready to begin again. Read all the next chapter up to Step 6, following all intervening steps.

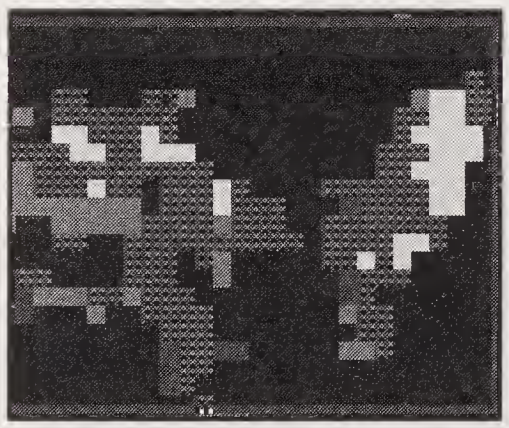


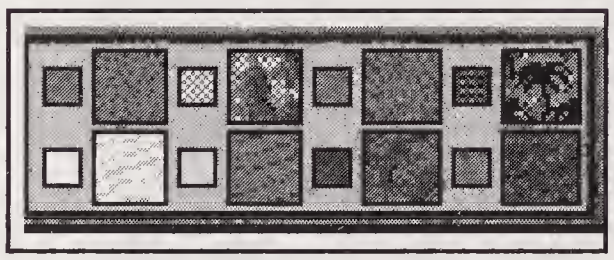
SWAMPS

Each biome looks different on the Map and Edit windows. You can use the legend to identify swamps or other biomes you're looking for. Then move the Edit Rectangle to select an area in the Edit window and you'll get a closer look.

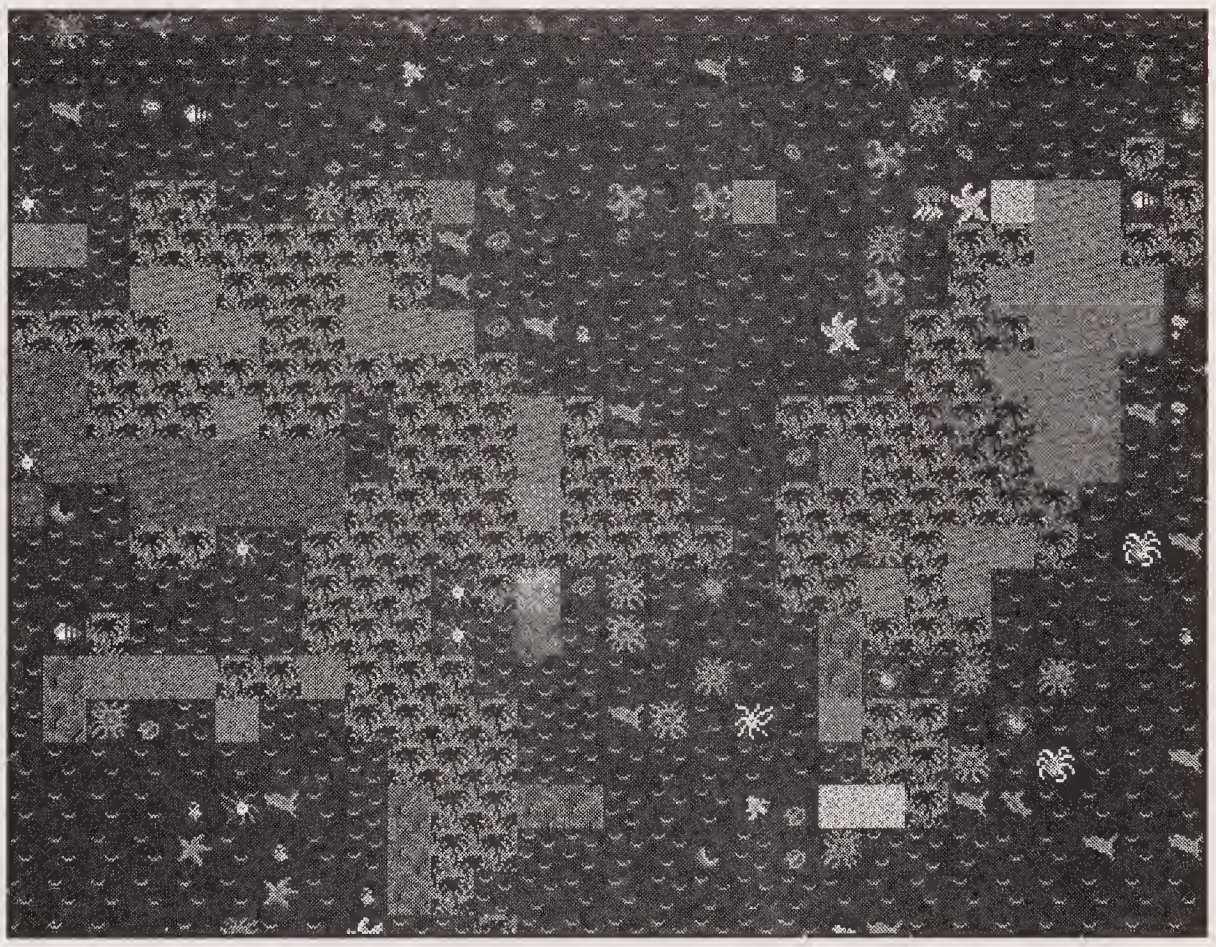
Here you'll see the part of the Map window bounded by the Edit Rectangle, the Biome Legend, then the part of the Edit window selected in the Map window.

The Edit Rectangle section from the Map wndow.





The Biome Legend.



The Edit window.

Raising or lowering rainfall can have an effect on biomes. A slight nudge of the Rainfall control on the Atmosphere Model Control Panel can dramatically change the biome distribution. If you don't have enough swamps, try raising or lowering the Rainfall setting. Lowering it will change tropical forests to swamps. Raising it will change grasslands to swamps. Find the dominant biome and see if you can decide what will happen.

Maui, the Hawaiian Demigod: *Depicting an ancient Hawaiian legend of the god Maui as he snares the Sun to help his people. This legend recognizes the importance of the Sun in our lives. Painting by Thomas Christian Wolfe. The original is in vibrant color.*

4 / The Sword and the Plow Civilization Models

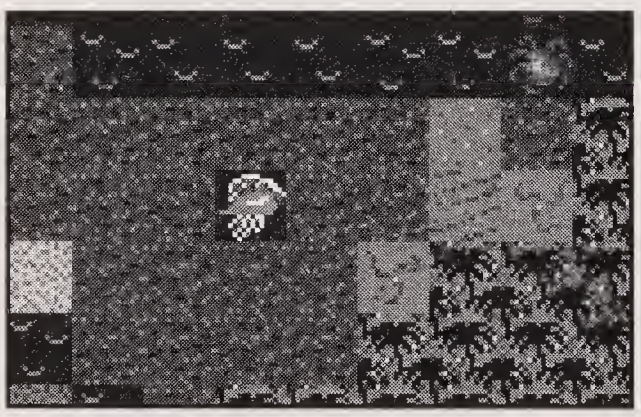
Time: 30 minutes
Or: 8,000–10,000 years
Current Goals: To help civilization crawl out of the Stone Age and reach Exodus to the stars; to guide the use of energy and promote intelligent life.

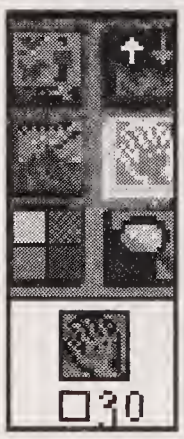
As you watch your planet develop, reflect for a moment on its fiery beginnings. You've come a long way. And you've probably done it in fewer than the Biblical six days (measuring in your elapsed time). If you've been successful, you've created a virtual Garden of Eden for intelligent life to inhabit. Now it's just a matter of waiting for that spark to ignite in the mind of some creature. Mammals won't evolve for millions of years after the emergence of the first multicellular creatures, but, in SimEarth at least, almost anything can develop intelligence. Therefore, your best bet for early life is probably the radiate. True, intelligent starfish and jellyfish are hard to imagine, but you may find that radiates can develop a perfectly hardy civilization—with a little help from their friend, the Planetary Manager.

Of course, there are other kinds of meddling you can perform. As Planetary Manager, it's your decision. You

could, for instance, use the Place Life tool to drop a few mammals onto your land and hope they survive. Or you could use one of the ultimate objects of meddling—the monolith. Although, to my knowledge this is just a figment of Arthur C. Clarke's fertile imagination, it is one of the tools in the G.O.D.S. kit. Use the monolith on a species, and you have a good chance of advancing that species to intelligence. The cost is high, though. It's 2500 EU to use the monolith, and it may not work! Still, if you want to use it, go ahead. I prefer to stay with more minimal intervention. The challenge is greater, and G.O.D.S. record books record monolith intervention in a separate, less respectable, category. The star travel (Exodus) record with monolith intervention is somewhere around half a billion years! But the Planetary Manager who set the record, Xtlanicora Mdurimicuaro, was later found burned out in her laboratory—cause unknown.

The chances are that if you don't do anything radical at this point, radiates will develop intelligence within a few hundred million years or less. As previously mentioned, it helps to have some swamps to allow them access to land.





With the Mover Tool, place a 16th level radiate in a swamp, give him two sticks to rub together and hope for the best.

Or try this trick: You can increase the chances of radiates reaching intelligence just a little. Once they reach the 90 IQ level, look at the icon that represents the highest form of radiate. It should look somewhat like the Portuguese man 'o war (a huge jellyfish). On the Map window, these should show up as the darkest color or shade. Locate them in the Edit window and use the Mover tool to place them in water next to swamps. This may help.

When the radiates do become intelligent, you'll want to be prepared for them. Their early civilization will be very fragile. It's time to examine our formula for success in the civilization model of SimEarth.

Formulas for Success

Life is cruel. That we know. Natural selection weeds out the weak and unfit and rewards the strong and adaptable. In SimEarth, kindness and soft-heartedness are not necessarily the best qualities for a Planetary Manager. Of course it depends on what you want for your "people." If you want them to survive and eventually to reach the stars, unfortunately the quickest way there is not always the most pleasant. Progress often involves sacrifice and hard work.

The first order of business when your civilization begins is to make lots of people. There are too many ways to die in the early going, so you need to have a high birth rate. The factor that affects people production is agriculture. Everything else is secondary at first.

Hand in hand with the agriculture is the amount of work your people will perform. You'll need to guide them to work very hard.

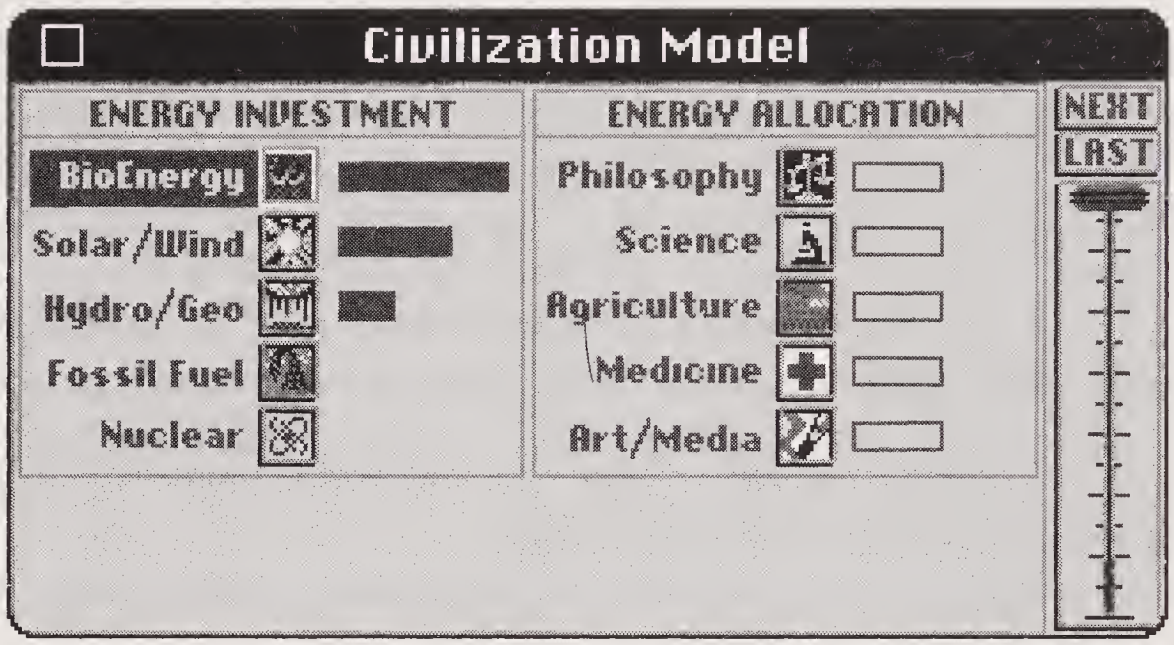
How do you control your intelligent species? Through the Civilization Model Control Panel. So now, before your first civilization forms, open the Civilization Model Control Panel and set things up for them. Although you could wait until intelligent life does form, they'll eventually thank you in person for paving the way so well (when they come to visit G.O.D.S. headquarters during their Exodus to the stars).

1. **Open the Civilization Model Control Panel by clicking on the Civ button in the Map window, by selecting it from the Models menu, or by clicking the Next or Last buttons on any other model window until you cycle to it.**

What you do next depends on how much energy (EU) you have left. It costs a lot of EU to change each setting on this window. There are two very important ones to change and several others of somewhat less importance.

2. **The first thing to do is select Agriculture and push the slider to the top.**

This is the single most important area of activity for an early civilization. This action will cost you 150 EU.



The next thing to do is to invest more energy into energy. That's right, you need to tell your species to get to work.

3. Select Hydro/Geo and slide it to the top as well.

That's another 150 EU.

4. If you have enough, invest another 150 EU and slide up Solar/Wind as well.

Remember, there won't be any immediate effect of these actions, but they'll take over as soon as intelligence develops.

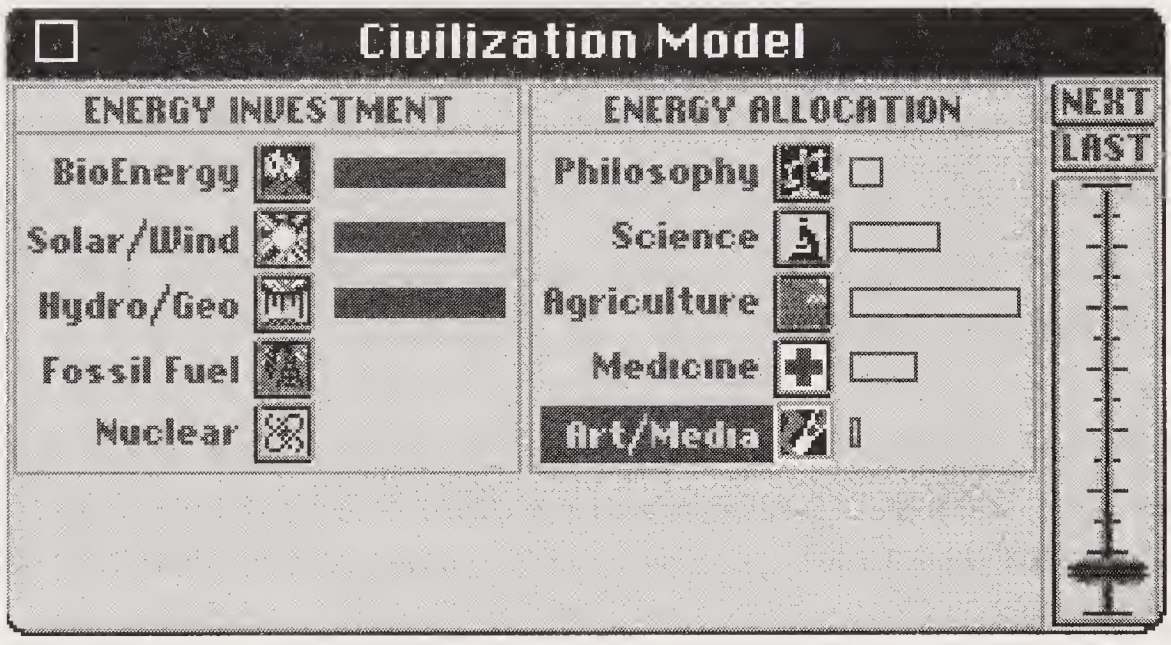
5. (Optional) Lower Philosophy, Medicine, and Art/Media a couple of notches each.

This means that your "people" will be brutish, mean, sick people, but they'll have lots of babies. Later, when they've started to spread out across the planet a little, you'll raise Science a notch or two. This will help them develop to a more advanced civilization more quickly. They'll be more efficient then, and can have more babies.

This is a fairly cynical view of an emerging civilization. I know, when I first became a PM, my first impulse was to

raise levels of Philosophy (which helps avoid war), Art/Media (which improves life quality), and Medicine. But at this stage, perhaps the hard line is the most kind. Without a complete dedication to population, your early civilization stands a good chance of dying before it can get started. This is especially true of radiates, who will probably be the species that develops if you've been following along. Radiates have the unfortunate habit of seeking to settle on land. But they can only live in swamps, and swamps are usually not in large supply and can often disappear suddenly with climatic changes. As we said before, if you do expect intelligent radiates, it's a good idea to keep a pretty toasty planet. You'll find more swamps in such an environment.

However, radiates do have one very definite advantage. They can live and thrive in the oceans. As you'll see, this can make things much easier later on.



The high population settings.

Now it's time to wait. Keep the climate stable if you can and wait for the magic of intelligence to appear.

The Dawn of Man... er, Radian

Although this section assumes that radiates will achieve sentience first, it is possible that another species will beat the radiates to civilization. That is unlikely if you've followed the previous steps perfectly, but very little is predictable in planetary development.

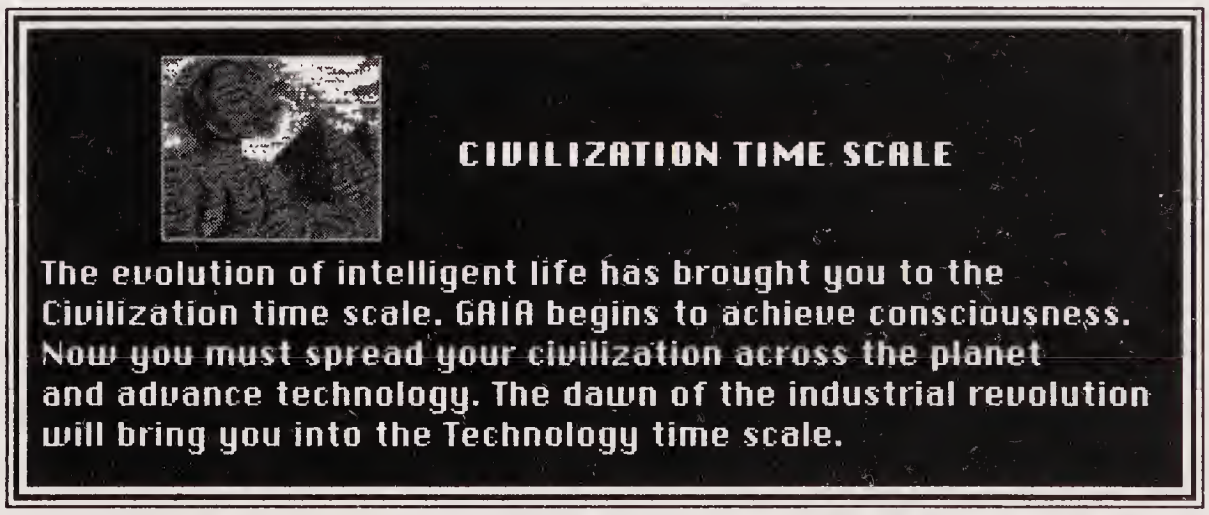
You have two options if radiates aren't the ones who discover fire. First, you can wipe out the other civilization (a plague works remarkably well if you're fast). Chances are that the same species will regain intelligence immediately, though, so you may also want to eradicate that species (I know, it's tough) by holding down Alt (Option on the Mac) and selecting that species from the Place Life palette. That gives the radiates another chance.

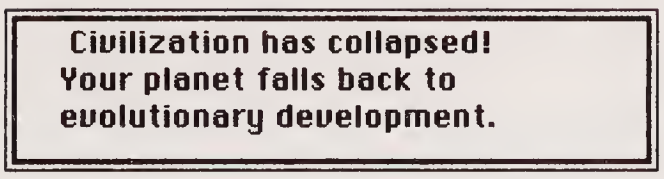
The second option is to proceed with a non-radiate civilization. Almost all of the information in this chapter still applies. However, if the other civilization is a land-based critter, make sure you have plenty of land for them to settle.

The beginning of civilization is signaled, like most major events, with some additional feedback and fanfare. Enjoy the moment, because you are about to work very hard to keep this moment from becoming a sad statistic.

If you're not careful, this →

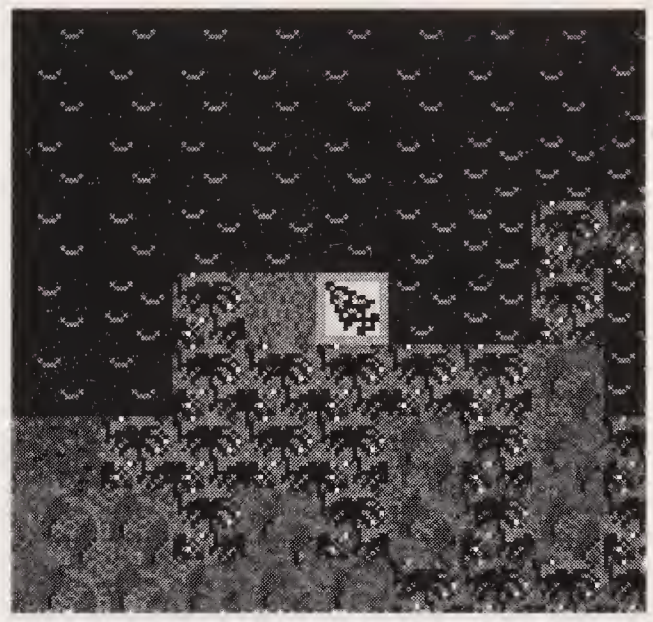
can turn to this.





As soon as civilization appears, the Edit window will shift to the location of the first city. It will be a Stone Age city, weak and just starting out. It may even appear as a single radiate.

You'll notice that, with the advent of the Civilization Time Scale, the Life setting in the Edit window is turned off. Leave it that way so you can identify intelligent travelling creatures from the rest of the mishmash of planetary life. You'll see why this can be important pretty soon.



The first radian city.

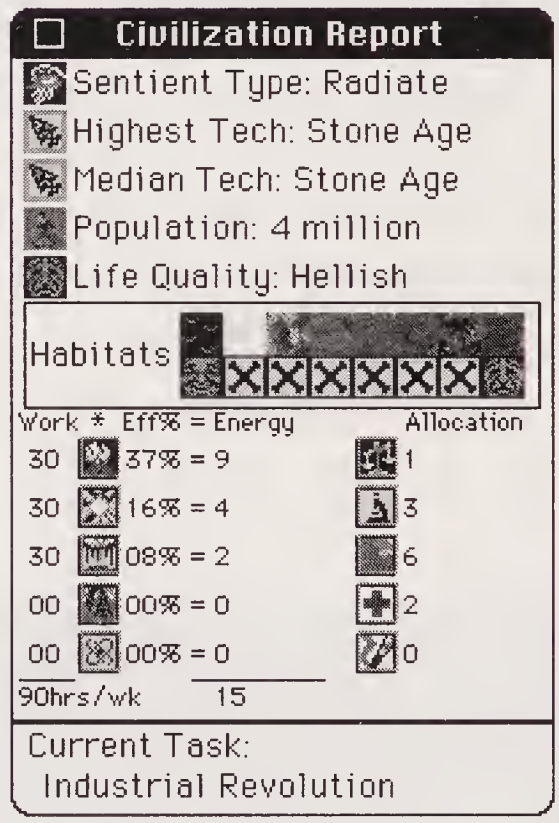
6. Pause the game and save it as *Tutor4* before anything else happens.

7. Next, click on the Civ icon in the Map window palette.

This will show the locations of all cities on the world map.

8. Now open the Report window (if it isn't already open) and examine it.

You'll notice that it is now called the Civilization Report. It lists some very useful information. At first, the main item of interest is the Population figure. If it is generally rising, your civilization is doing all right. If it declines steadily, they may be in trouble.

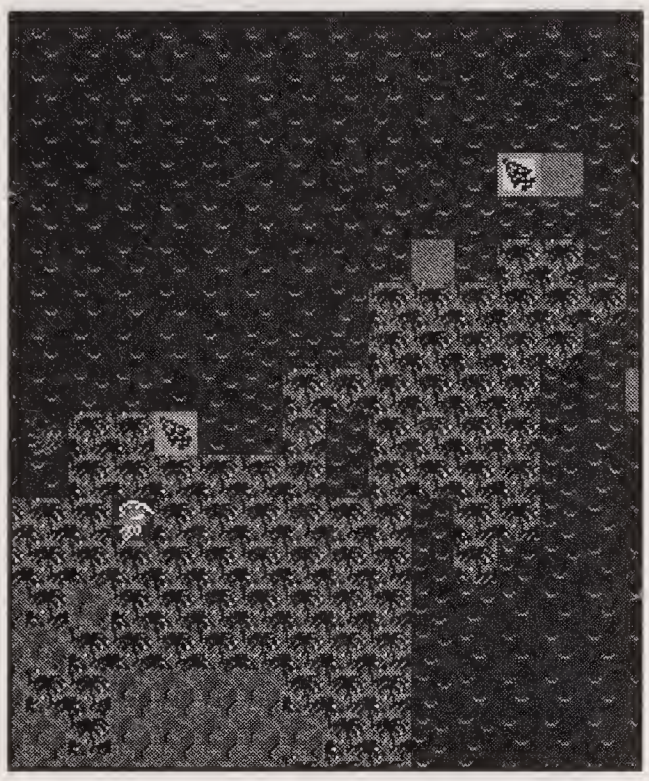


Look at the Work * Eff% = Energy listing. This shows the amount of energy the civilization has to work with. Efficiency rises with technology. Across from the energy numbers is the allocation list. This shows how much of the available energy is used for each task. If you've set this up right, Agriculture should be the highest number, Science second, and everything else third. These numbers directly reflect the settings you made in the Civilization Model Control Panel earlier.

(If you don't understand the relationship between the items on the Civilization Model Control Panel and the information in the Civilization Report window, try lowering the level of one of the energy settings. Lower Solar/Wind, for instance, and see what happens. Or try

lowering Agriculture to a minimum level. However, if you try these experiments, be prepared to Load *Tutor4* again and start from where you were before.)

9. Start the game again (preferably at Slow speed).



This image shows three Stone Age cities: a strong, healthy one, a weak one, and a traveling city that looks like a level 16 radiate.

Notice that the time scale has changed again. Now, instead of counting off 250,000 years at a time, each "tick" is only ten years. Still, a lot can happen very quickly even at this speed of development.

You can tell a lot about the health of any individual city. When they first form, cities are weak, and the city icon shows that. On color systems, they are only outlined with color. On B&W systems, they show as outlines of dark on a light city icon. A healthy, well-populated city is all colored in or dark. When a city forms on a biome that the life form only tolerates, it will never develop to the most populated level. For instance, although radiates can live in swamps, they don't tolerate them as well as they do the oceans. Therefore, cities that develop on the swamps will never be as populous as the ones in the oceans, and their icons will reflect this.

One of the facts about intelligent radiates (what we at G.O.D.S. like to call Radians) is that they aren't all that intelligent, especially early in their development. They will keep trying to settle on land that is unlivable. Therefore, they will have a very hard time getting established. Why they do this instead of populating the vast oceans, is a mystery locked forever in the radiate mind (or in the minds of Will Wright and Fred Haslam anyway).

There is a solution, however, but it will require a bit more Planetary Manager messing about. The trick is to take the travelling Radians (the ones who emerge from the cities and start to move around over land) and move them to new locations in the oceans where they may settle. Sometimes they don't take the hint, but often you'll find an ideal spot for them and they'll just put down roots (tentacles?) and get to the work of making more Radian babies.

Note that the Radian cities on land will send out many more travelers than those in the water. So it's a very good idea to have at least one city in a swamp. Grab traveling cities as they emerge.

If you made the settings in the Civilization Model Control Panel earlier, your first city should start making new Radians pretty soon. There's also a chance that the first city will pick up and start traveling (meaning they weren't really happy there and want to move to a better neighborhood). If they don't find a place to settle soon, civilization will collapse. You can help by moving them to a suitable location. If there's a nice continental shelf bordering on a swampy area, that's a good bet for starters.

10. Select the Move tool from the Edit window palette, pick up a moving Radian and move it to a new location.

It costs 30 EU each time you do this. You could simply drop a new Stone Age city on the map somewhere, but that would be more expensive and certainly more unrealistic.

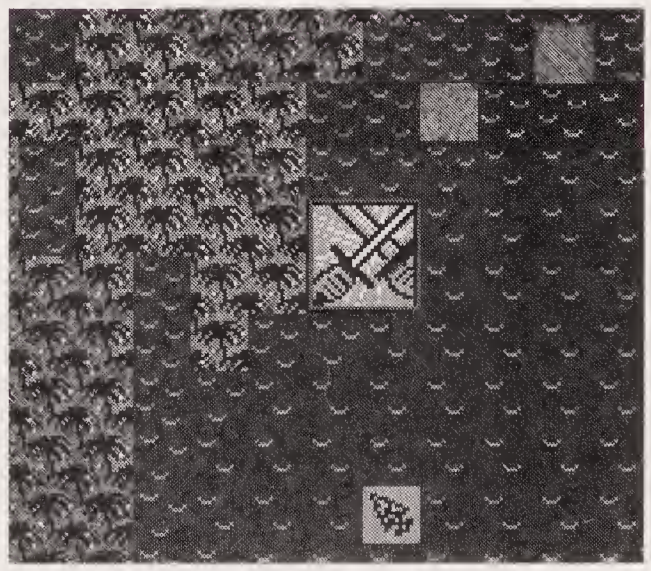
Think of it this way. You, as Planetary Manager, are simply influencing the existing population to relocate (perhaps through visions—burning bushes and the like—or other methods). That's more believable and less blatant than just plopping a city down out of nowhere. Besides, it only costs you 30 EU to move a creature. It costs 500 to drop a Stone Age city! Finally, the rules don't allow you to drop cities like that if you want to make the record books.

While all this is going on, keep an eye on the climate. You may notice a significant change in air temperature. If you think action is warranted, you might correct it. Or, you might choose to move your civilization to a more hospitable region.

11. You may want to Pause the planet again as you read the next sections.

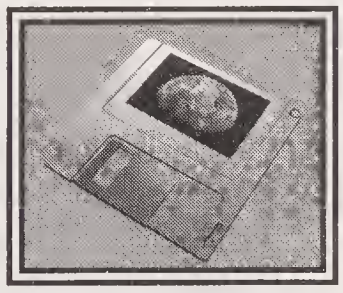
As your cities grow, population will begin to expand and life quality will soon reach the "Hellish" stage. Sorry, but life in the Stone Age wasn't the height of luxury, so don't worry too much about it for now. Survival is more important than comfort. Isn't it? Anyway, comfort is a relative term.

Your chief enemies will be wars and plagues. Whole cities will disappear periodically. However, if you keep moving the wandering Radians to new locations and they keep establishing new cities, your population will expand



The scourge of war.

faster than wars and diseases can decimate them. As your population expands, notice in the Civilization Report window that the available energy increases as well.



The Quality of Mercy vs. the Quality of Life

The quality of life for your SimEarthlings is probably quite important to them, but from the point of view of a Planetary Manager, it can be completely unimportant. Unless the quality of life is the actual goal you've set, it has no bearing on other factors in the simulation. There won't be more wars or more plagues because the people are miserable. Nor will their birth rates decline or rise. In fact, the quality of life makes no difference. Therefore, for maximum effect, you can leave your creatures in the Hellish state with no penalty, other than possibly an unpleasant encounter with them when they arrive at G.O.D.S. headquarters to complain. But by that time, your mission will have been accomplished.

The formula for the quality of life is generally related to the Art/Media setting divided by the amount of energy produced multiplied by the total population. If Q is Life Quality; A is Art/Media investment; E is Energy produced; and P is Total Population, the formula would read:

$$Q = A/E * P$$

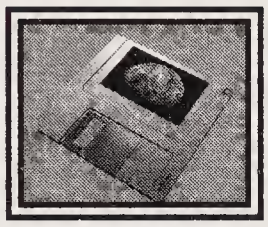
Obviously, as population increases, quality of life tends to become worse. And the more hours of work the people have to do, the worse their life quality becomes. Since the total energy output of a society is a function of the hours they work, the more energy (work) they produce, the more difficult their life.

The Bronze Age

When the Bronze Age begins, the situation is still touchy. However, the more Bronze Age cities you get, the safer civilization becomes. That's because the Bronze Age citizens (and those of each successive civilization) are more efficient than those who came before. So for the same investment in hours of work, they gain more energy in return. This makes them more viable. But at first, until the Bronze Age has spread, the civilization is still very vulnerable.

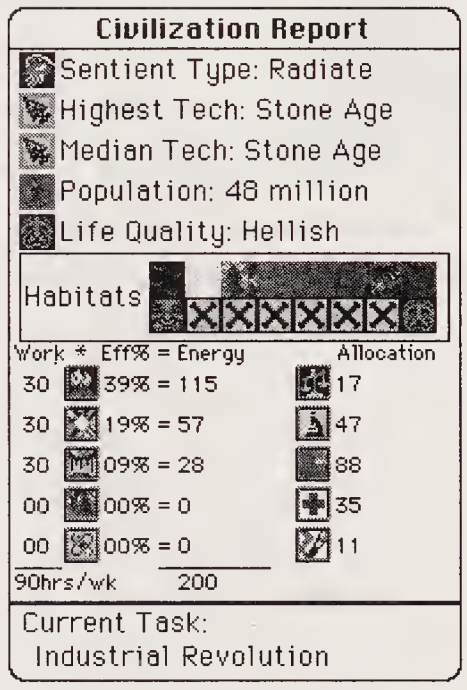
You may also notice one additional advantage to new technology. For some reason, your energy units (EU)

replenish faster as technology increases. It's another mystery of the G.O.D.S.



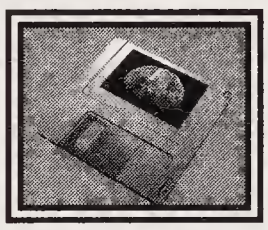
Energy Unit Replacement by Tech. Level

Tech Level	Increase Rate
Stone	2/cycle
Bronze	3/cycle
Iron	4/cycle
Industrial	5/cycle
Atomic	6/cycle
Info	7/cycle
Nano	8/cycle



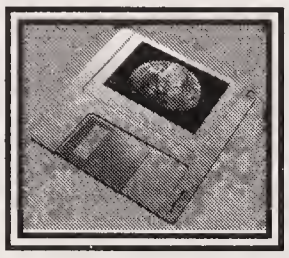
Report just before Bronze Age.

When the Bronze Age cities begin sending out travelers, you'll notice that these new wanderers have different icons. Each successive development in civilization will have different travel icons. Try to get these Bronze Age travelers to settle in new places.



City and Traveling Icons

	City	*Land*	*Sea*
Stone Age			
Bronze Age			
Iron Age			
Industrial Age			
Atomic Age			
Info Age			
Nanotech			



How Societies Advance

The way civilization develops in the SimEarth model depends on the amount of energy produced by a civilization. After each "tick," the total amount of Science energy the Sims produce is lowered by 20% and added to a rolling sum of previous energy values. Eventually, if the civilization reaches consistently high levels of Science energy production, they will advance to the next level of technology. The chart shows how much energy is needed (in the hidden sum) to reach the next level. The second value shows the approximate total energy production per tick needed. This figure will vary greatly depending on the Science setting.

Civilizations will advance at different rates. For instance, if the Science setting on the Civilization Model Control Panel is high, the sims will advance faster. If it is low, they will advance slower. And, as usual, there's plenty of randomization to make predictions nearly impossible. Still, the information in these charts should help a little.

At first, you may have a hard time getting budding civilizations to prosper. However, with patience and a little luck, your creatures will eventually reach the Bronze Age and beyond.

Chart of Energy Requirements for Technological Advancement

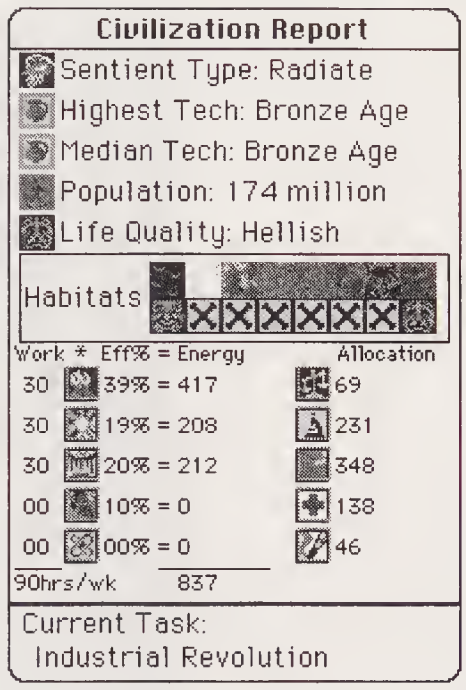
Tech Level	Hidden Sum	Energy Produced
Bronze	> 200	@200-400
Iron	600	@550-800
Industrial	6000	@6000-7500
Atomic	10,000	@10,000-12,000
Info	20,000	@20,000 or more
Nano	30,000	@30,000 or more
Exodus	80,000	@60,000 or more

Chart of Energy Efficiency by Technology (averaged)

Tech Level	BioEnergy	Solar/Wind	Hydro/Geo	Fossil Fuel	Nuclear
Stone	40%	20%	10%	0%	0%
Bronze	40%	20%	30%	10%	0%
Iron	60%	20%	30%	30%	0%
Industrial	60%	30%	50%	80%	10%
Atomic	70%	50%	50%	80%	80%
Info	80%	60%	60%	90%	90%
Nano	90%	80%	80%	90%	90%

Don't waste your 30 EU on the Stone Age wanderers any more. They're history. It's time to boogie with metal! And just think, the Iron Age is just around the corner!

Once the Bronze Age really begins to radiate (and that's a pun) out into the world, your population should grow steadily. Now you might even take pity on your folks and raise Arts/Media a teeny weeny amount. Not too much. Just enough so life is merely Miserable, not Hellish. Or, you could raise Philosophy a little. It all depends on how much energy you have left and whether population is growing fast enough. You'll have to make such decisions yourself.



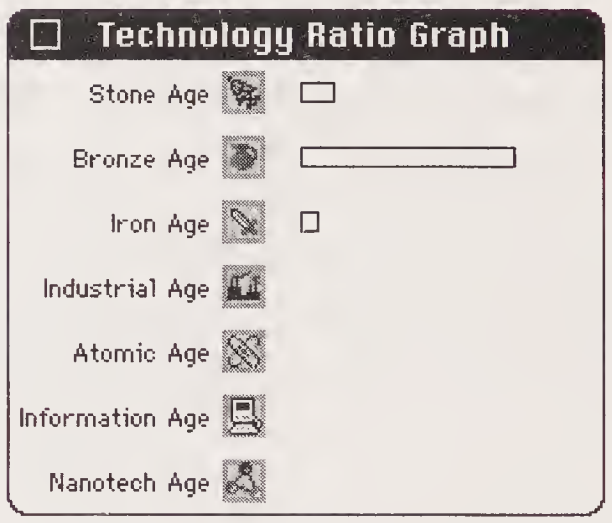
Near Iron Age.

The Iron Age

Finally, before very long, the Iron Age will appear. This is usually a signal that your civilization is pretty well established. The Radians should begin to spread out much faster now, and need less help from you. You can probably relax for a while, but you'll need to keep a close eye on the History window and the Air Temperature and CO_2 levels.

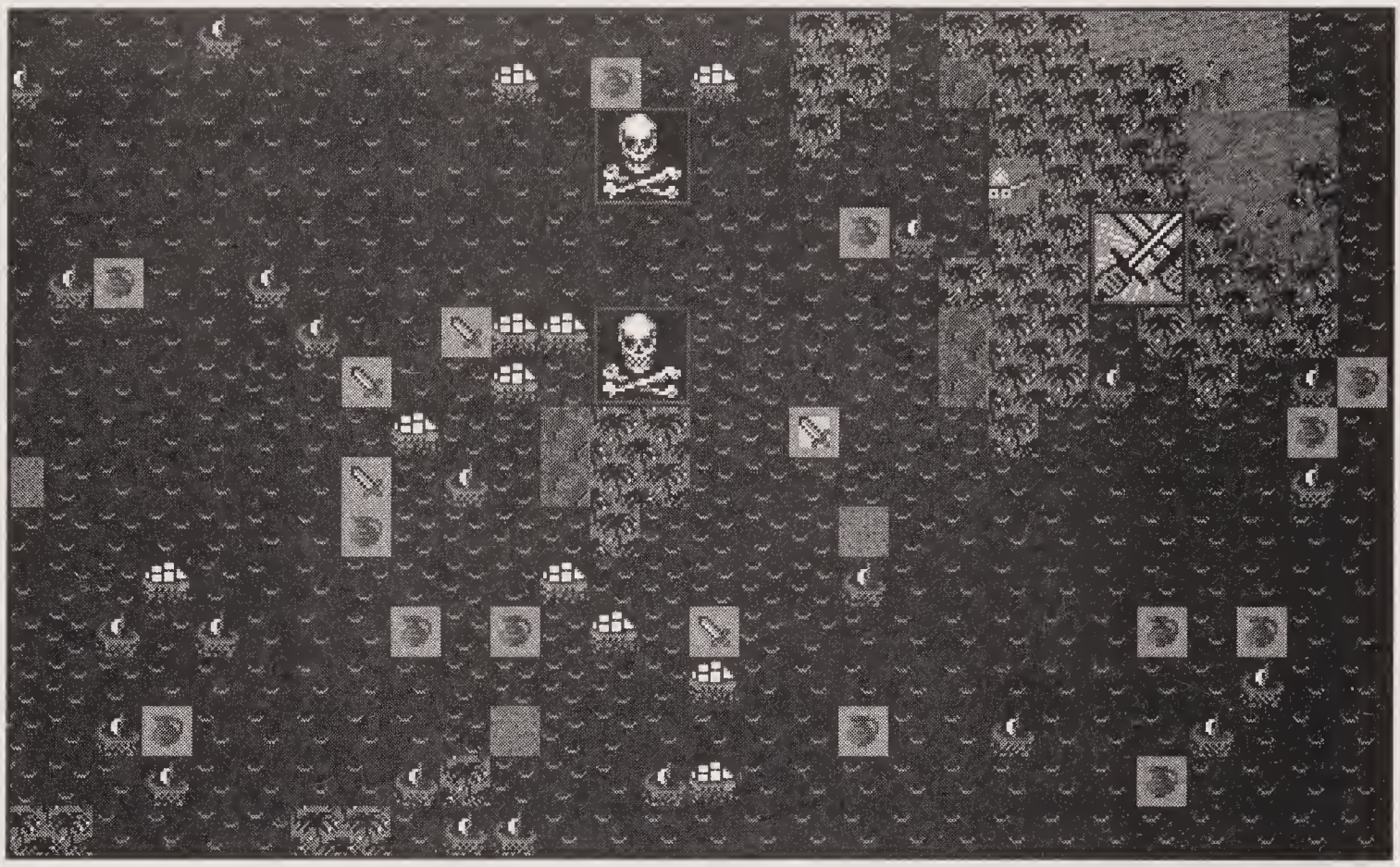
12. With the advent of the Iron Age, open the Technology Ratio graph (from the Graphs menu).

Now you can see, in graphical form, the ratios of the various technologies on your planet. This, along with the Median Tech reading on the Civilization Report window, should give you a good idea of the development of your intelligent species.

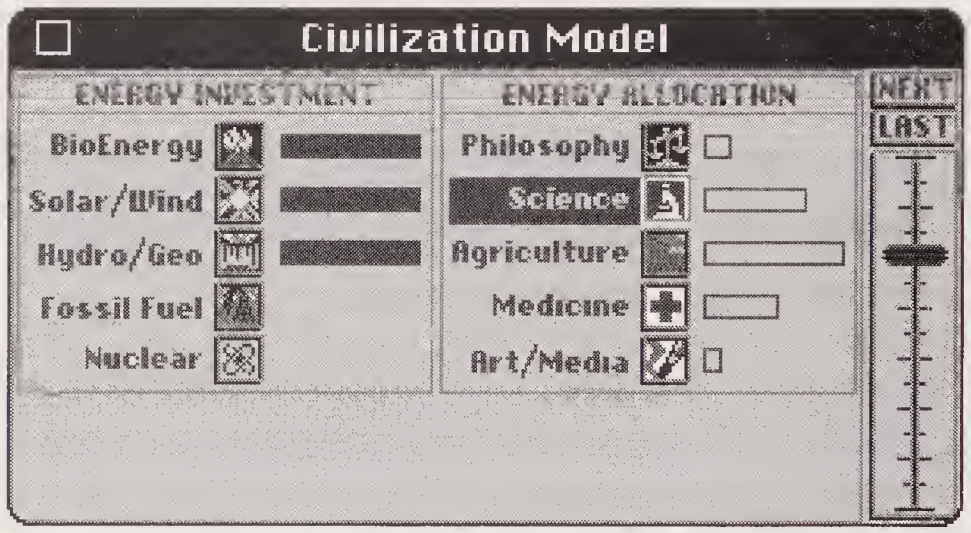


13. If things look pretty stable, set the simulation to Fast speed. It'll get you to the next stage of evolution with remarkable alacrity.

As population density increases and cities appear closer and closer together, plagues will become an increasing problem. You may want to raise the level of Medicine in the Civilization Model Control Panel. Wars are still a minor annoyance, but plague can wipe out a whole area where cities are close together.



Plague and war in the Iron Age.



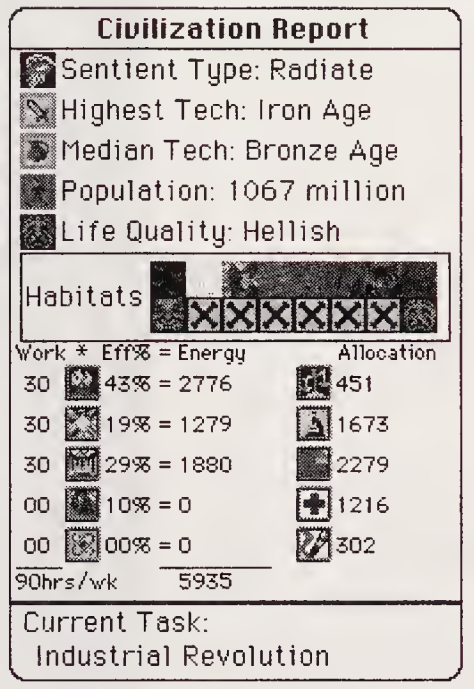
14. Switch to (or open) the Civilization Model Control Panel and raise the level of Medicine a notch or two.

The Technology Time Scale

Civilization now develops even more rapidly, and, almost before you know it, the Industrial Age will begin. The rate of change in your world will accelerate. You're now officially out of the Civilization Time Scale and into the Technology Time Scale.

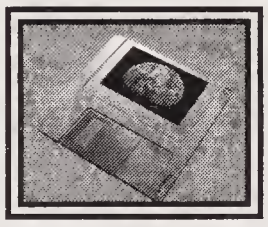
You may be tempted now to start using fossil fuels. That's your prerogative. Ancient civilizations tried that method, but lived (barely) to regret it. Have faith. Your civilization can do quite well with the energy sources they are already using.

Even if you don't use the fossil fuels, you'll find a pollution problem beginning to appear in the Industrial Age. In addition to factories belching smoke into the atmosphere, there will be oil slicks (how that happens when they're not using fossil fuels remains a mystery to this day). However, your people should develop quickly out of the messy Industrial Age and into the tricky Atomic Age.



Near Industrial Age.

Again, don't start using Nuclear fuel, unless you like atomic war. The best bet is to wait still longer, using all the other, more renewable sources of energy. The Atomic Age is less polluting than the one before it, but you should continue to watch the environment. Watch also for increasing frequencies of plagues.



The Fuel Dilemma

Using fossil and nuclear fuels in SimEarth can produce some unpleasant results. While it does increase energy output, it also has some side effects. For instance, as these non-renewable fuels begin to run out, people will start to fight over them. World wars will break out, and if nuclear use is up, the war can be a deadly nuclear war. One result of an all-out nuclear war is nuclear winter, which can wipe out most life on the planet. Another result is toxic, irradiated sections of the planet that are unfit for life for thousands, or even millions of years.

Possible results of using fossil fuels:

- Depletion of the scarce resource.
- Local pollution (oil spills and toxic emissions).
- Rising carbon dioxide and greenhouse warming.
- World war.

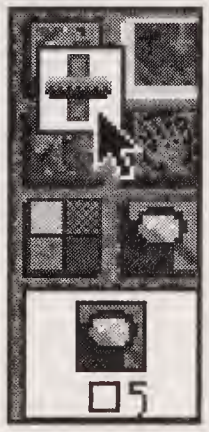
Possible results of using nuclear fuels:

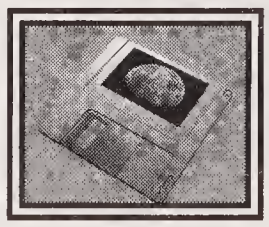
- Depletion of the scarce resource.
- Nuclear war.
- Radioactive areas.
- Nuclear winter.

As the Information Age begins, population is rising fast and plagues can become a serious problem.

Finally, the Information Age begins. Your Radians are almost there. They'll spread out over the planet at increasing rates, and their population will reach a maximum—at least several billion individuals. Now plagues can become a real problem, and you may want to put both Medicine and Science up high while finally lowering Agriculture just a bit (maybe a notch or three).

It's a secret!





Population Density

Population on any planet eventually reaches its limit. In the SimEarth model, once a certain density is achieved, the population simply won't expand much more, even if you try all your tricks. The only thing that will work is to give them more room to expand. With land-based creatures, you can (carefully) create new land with volcanoes, with the Raise/Lower Land tool, or even (on Macintoshes) by lowering the oceans using a hidden trick (see the Reference section under The Secret Raise/Lower Oceans Trick).

The opposite is true of sea-based life forms like the Radians. Get rid of more land areas, and they'll expand into any new ocean areas available. Eventually, with high technology and huge populations, the sky's no longer the limit.

15. Once they enter the Information Age, raise Science and Medicine to their maximum values. Lower Agriculture a notch or two.

Now, if your people can keep growing just a little longer, they'll reach the Nanotech Age. This is it. They are almost there now. One more step in their evolution and they'll be ready to take off for the stars and leave their world behind as a nature preserve. It's the culmination of the dreams of countless generations of Radians. Much of their art and literature (what they had of it) has looked to the stars, and their science has aimed that way for years. Of course, they have no idea that you've been behind the whole thing.

You may have noticed that your civilization can evolve all the way to Nanotech levels, but there can still be Bronze Age, and possibly even Stone Age cities on the planet. There may also still be dinosaurs roaming the countryside. Part of the fun of your job is to see different civilizations coexist. And part of your future fun will be seeing new species reach intelligence once the current one has departed.

From this point on, you shouldn't need to do much else. Read the rest of this chapter as you watch the progress of your civilization. You're so close now that all you have to do is make sure population continues to increase. If you have followed the directions in this section, that should continue steadily. What you do now depends on whether you feel like waiting a while or speeding things up still more. It's probably only a matter of years now.

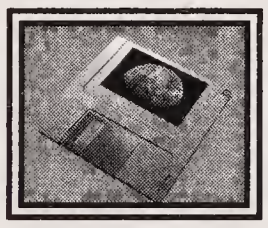
If you are working with a civilization other than the Radians, one that lives primarily on land, you may need to use the fossil fuel and nuclear solution outlined below.

With patience, your Radians will probably make it to Exodus without any more help from you. If you wait until they have a population of more than 5 billion and they are turning out around 60,000 units of work energy consistently, they'll

probably take off. A good setting on the Civilization Model Control Panel is to place Science, Agriculture, and Medicine all at the maximum with Philosophy and Arts/Media relatively low.

Or you can give them one last push. Their combined work output must be at least 32,000 units of energy, though your Radians may be far beyond that already. Now, with a predominance of Information Age cities and a good scattering of Nanotech cities, you can push them to the stars by suddenly turning up Fossil Fuels and Nuclear all the way to the top. It will only take a few more "ticks" before they take off, though you may use up all or most of the available fuels in the process.

Once they begin to take off, reduce Fossil Fuels and Nuclear to zero again. You may not know it yet, but the fun has just begun. There will be another species that develops intelligence, and, with many billions of years to spare, you can launch a veritable zoo of sentience into the interstellar wastes. We at G.O.D.S. always say, "It's a big universe and you can't have too many friends."

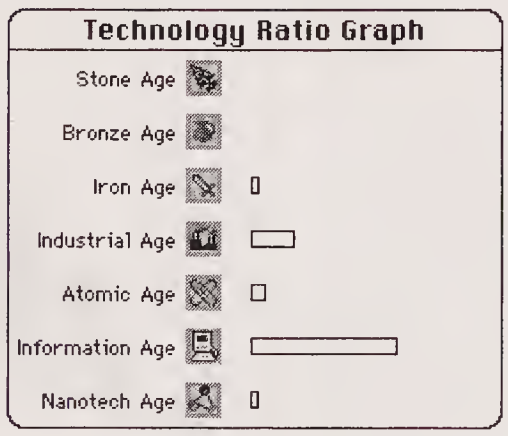


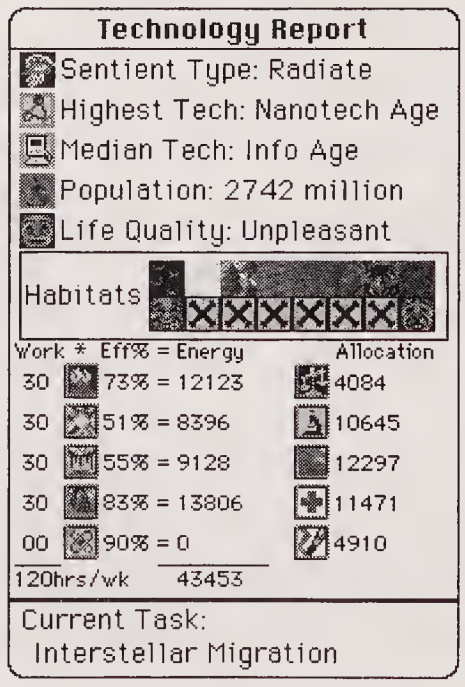
Preparing For Exodus

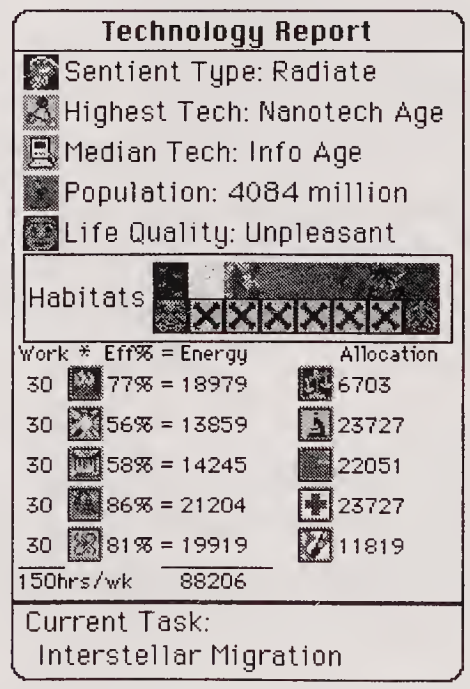
Once your civilization reaches the Nanotech Age, they are ready to take off. It's just a matter of energy and science working together. Below is a Technology Ratio Graph that shows the minimal amount of Nanotech civilization you'll need. Next to the graph are two reports.

The first report shows a civilization that could go to Exodus very soon. They just need a little more energy.

The other report shows a world that's maxed out–huge population, lots of energy, and all ready to go.

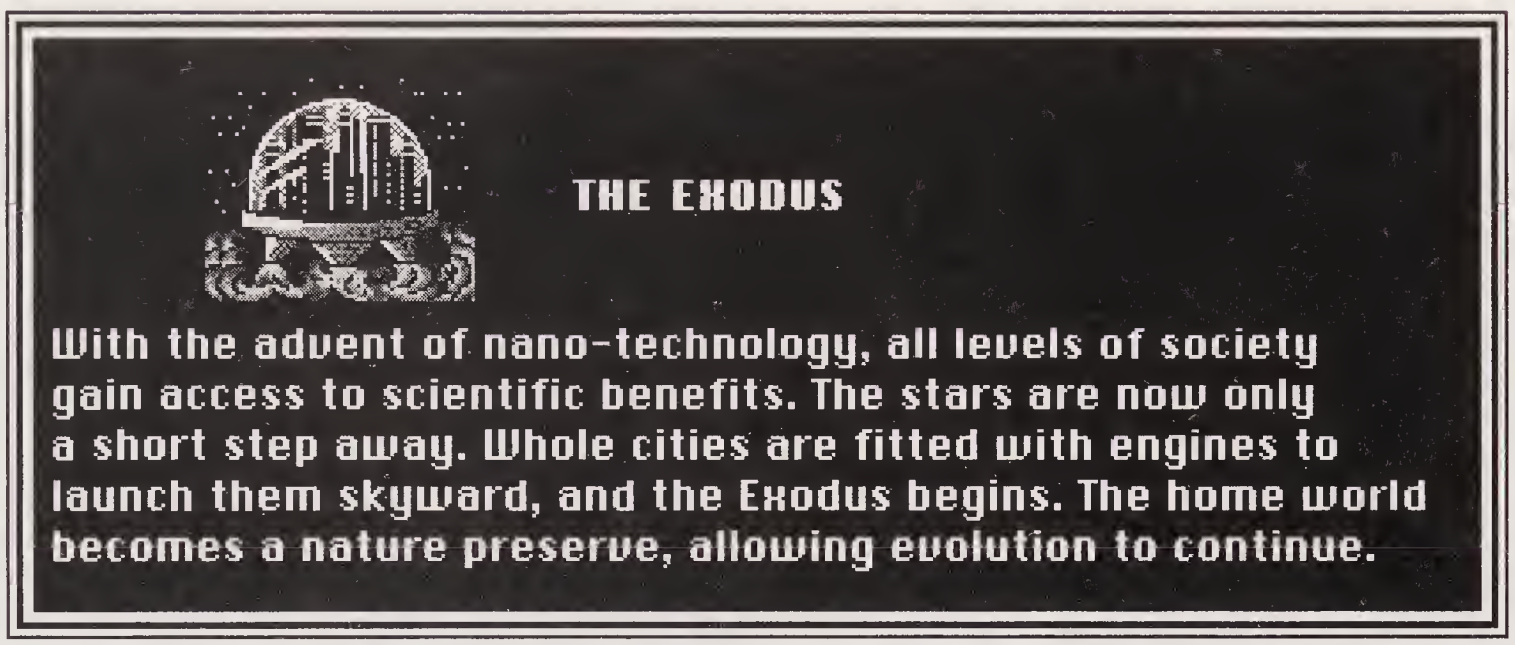






Congratulations. If you made it this far, you are a full-fledged Planetary Manager, well on your way to true knowledge. If you didn't set the speed record, it doesn't matter. You already knew that, didn't you? This was just your final exam. You passed.

Now go to it. See what other wonders you can create.



Part II

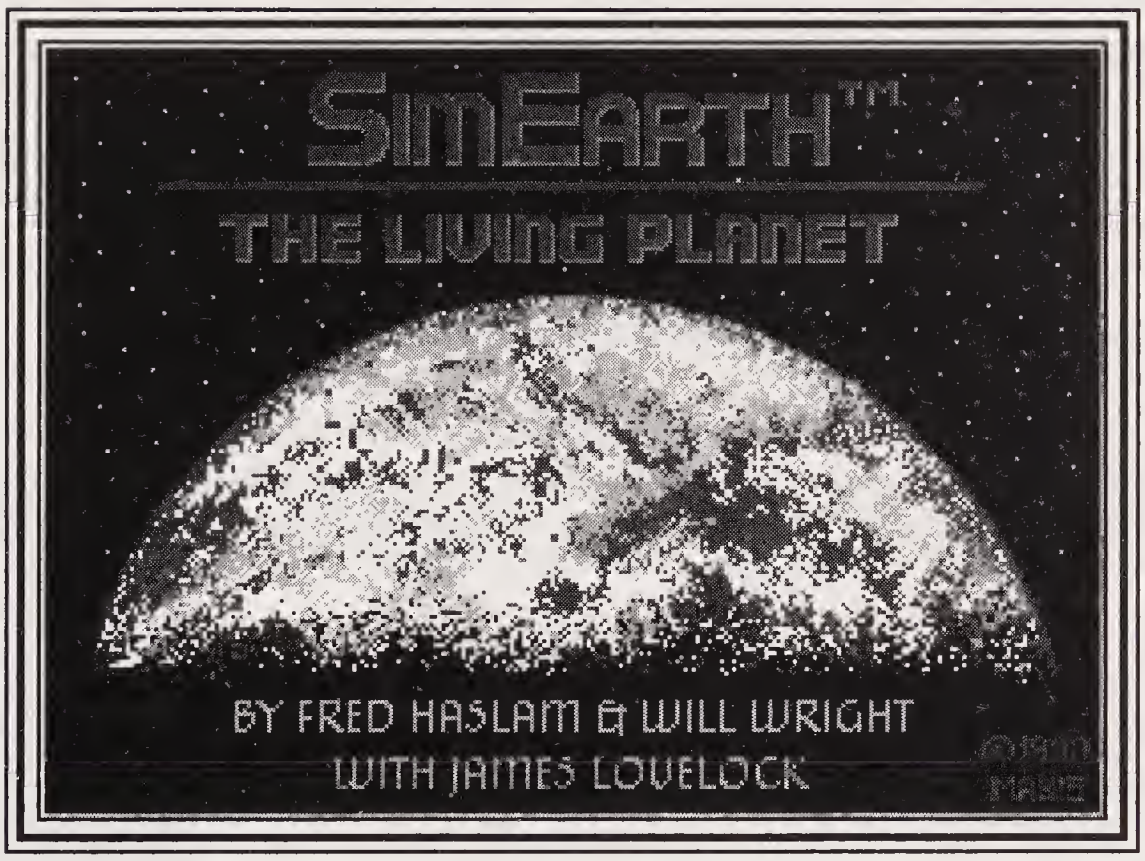
SimEarth—The Reference

While the earth remaineth, seedtime and
harvest, and cold and heat, and summer and winter,
and day and night shall not cease.
—Genesis 8:22

LEFT PAGE: Apollo 7 astronauts shot this great sunrise in 1968 from 120 nautical miles above the Earth. Below are the Gulf of Mexico and the Atlantic ocean.

RIGHT PAGE: The Moon taken from 10,000 nautical miles away as Apollo 11 returned home after their 1969 visit.

Part II
SimEarth—The Reference



In this section you'll find a wide variety of information ranging from basic procedures to use in SimEarth to insights into our modern world. You'll also find plenty of tricks and undocumented secrets about how SimEarth works. Even if you've already read the SimEarth manual from cover to cover, you'll still find new information here.

You may also want to refer to this section when you're playing SimEarth and you want to know more about the tools and windows.

Because SimEarth is a windowed environment, we'll look at the product from the perspective of each window. For instance, we'll look at the Map window as a whole, and also each of the main tools available on it.

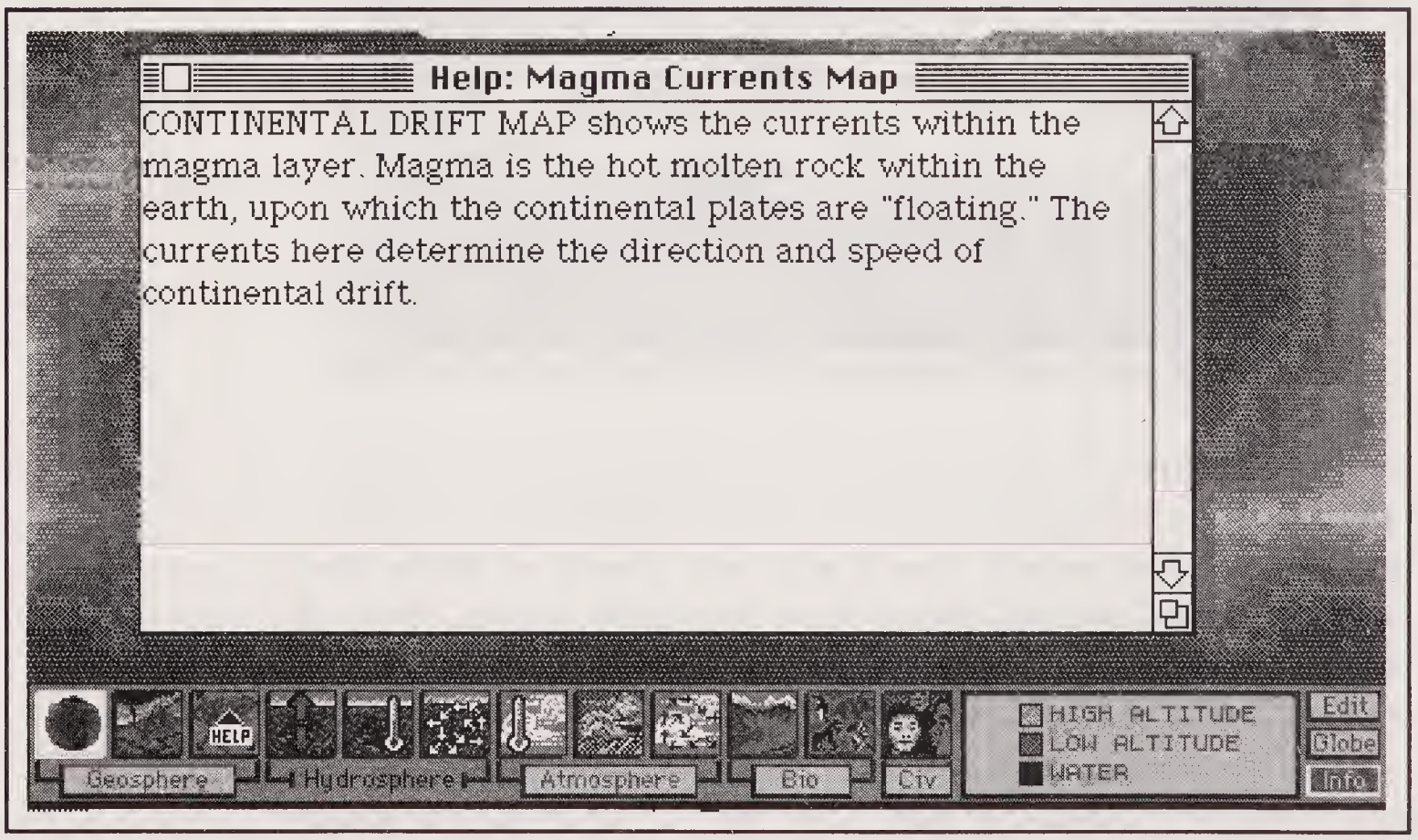
At the end of the Reference, we'll also look at each of the menu items.

THE HELP WINDOW

USING HELP

It's easy to find out what something does in SimEarth. The built-in Help system will tell you about almost anything on the screen. Simply hold down the Shift key and click on an object, button, or window. On systems with a two-button mouse, you may also press the right mouse button to access the Help mode, then click on an object, button, or window. An explanation of the item chosen will appear in the Help Window, which is a scrollable text window. It's the same window that displays the on-line tutorial when you first begin SimEarth. Or press F1 on some systems

The only exception to that rule occurs when you click in the Edit window itself. Here, if you are playing a limited energy game, you will be charged for energy units. That's because using Help in the Edit window serves the same function as the Examine tool (the Magnifying Glass).



Version Note: *On the Macintosh, where the Examine tool costs 5 EU, using Help within the Edit window costs you whatever the Current Tool setting shows. So if you're ready to drop a meteor at 50 EU and you decide to use Help to see check something in the Edit window display area, it will cost 50 EU to use Help. On the*

other hand, if you have the Current Tool set as the Magnifying Glass, it will cost you 5 EU, the same as the Examine tool.

Another odd behavior of the Mac Help system in the Edit window occurs in the icon palette. If you Shift-click on any of the six upper tool icons, that icon becomes activated, but the Current Tool icon does not change. For instance, suppose you had the Examine tool selected, then Shift-clicked on the Event Trigger icon. The Current Tool Display would still show the Magnifying Glass, but the Event Trigger icon would be highlighted. Whatever disaster you had last chosen would actually be activated if you clicked in the Edit window at this time. Be careful not to drop a plague or a meteor, for instance, on your people by accident.

You can review the on-line tutorial at any time by selecting Tutorial from the Windows menu. For a definition of terms, open the Glossary window (from the Windows menu).

If you are already quite familiar with how windows work, you may want to skip this section, but for those who want a refresher, read on.

WORKING WITH SIMEARTH

WINDOWS AND VERSIONS

Windows in SimEarth share certain common attributes. Each can be opened and closed, or dragged around the screen. Some windows can be resized to fit better in your monitor's available space, and all can be rearranged to suit your needs. Some show only part of their contents on the screen at once and can scroll to display more information. Others are fixed in size and do not scroll. Many windows contain additional buttons or icon palettes with which you can affect the simulation or your view of it. You'll learn about each available choice under the appropriate section of this tutorial.

There are several versions of SimEarth, and they differ in various ways. We've already mentioned, for instance, that the Help mode works differently on systems with a two-button mouse than it does on systems with only a one-button rodent. Although there are various other differences, we will note most of them in the appropriate places.

Some differences between the Macintosh and the IBM versions of SimEarth deserve special attention. On the Mac, you move around in the Edit window using scroll bars. The IBM version does not use scroll bars. Whenever you move the

cursor to the edge of the Edit window, it scrolls automatically. Move to any edge of the screen and the view in the Edit window scrolls as well. In addition, you can move from the right edge of the Map window and wrap to the left edge, and vice versa. The Macintosh version does not have this wrapping capability.

Also, the IBM and the Mac versions function differently when it comes to clicking on things. For instance, when you open a menu or palette of choices on the Macintosh, it will close as soon as you release the mouse button. On the IBM, the menu or palette will stay open, and you can click again to make a selection.

Likewise, on the Mac, if you click in the Edit window, even if it is not currently the active window, the current tool will be activated. So you need to be careful when clicking in the display area of the Edit window. On the IBM version, clicking in the Edit window only activates it. It does not use the current tool.

There are various other differences between the two versions, but for the most part they function the same. Where they differ, we have tried to indicate the differences in the appropriate sections.

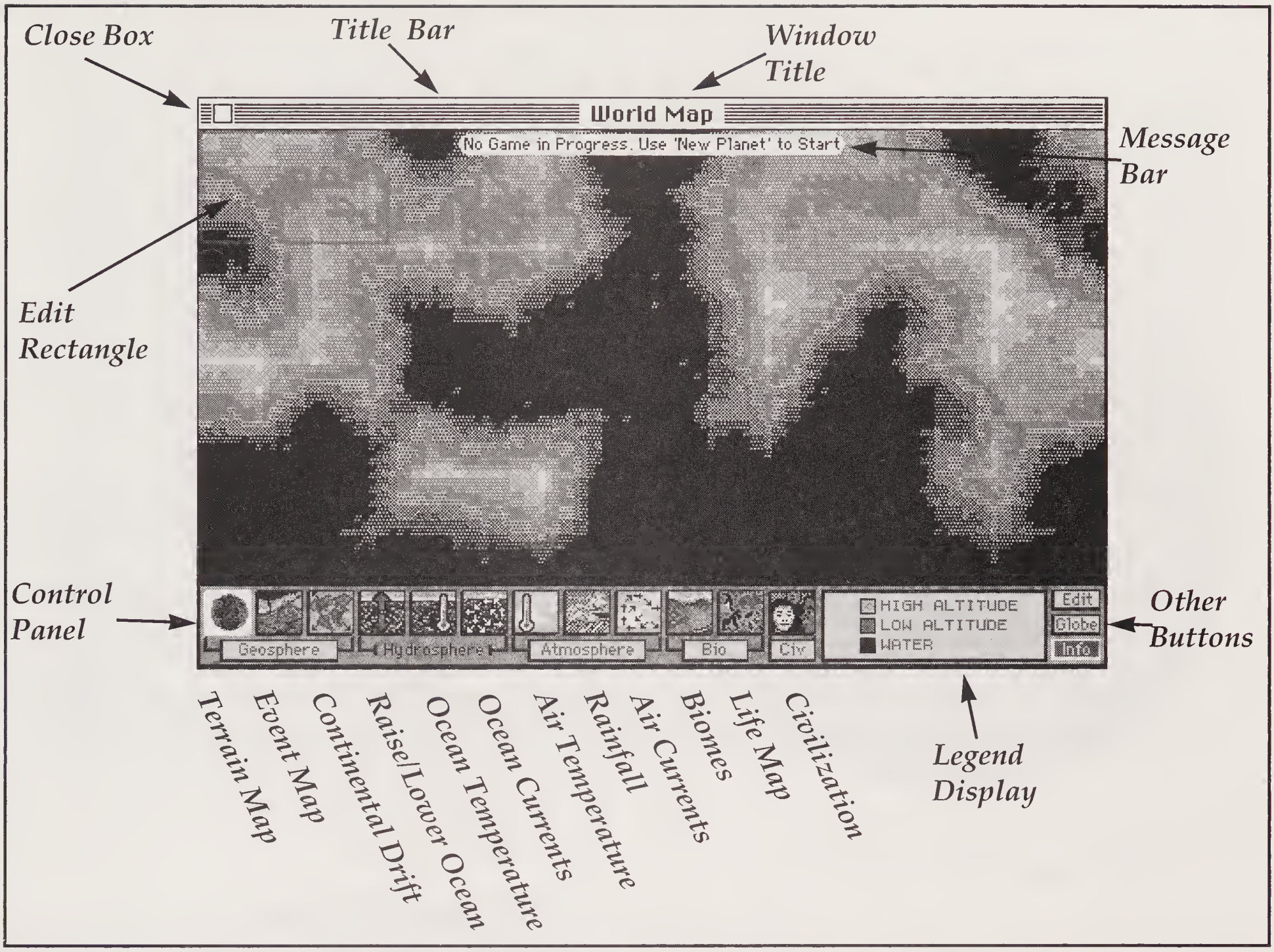
THE MAP WINDOW

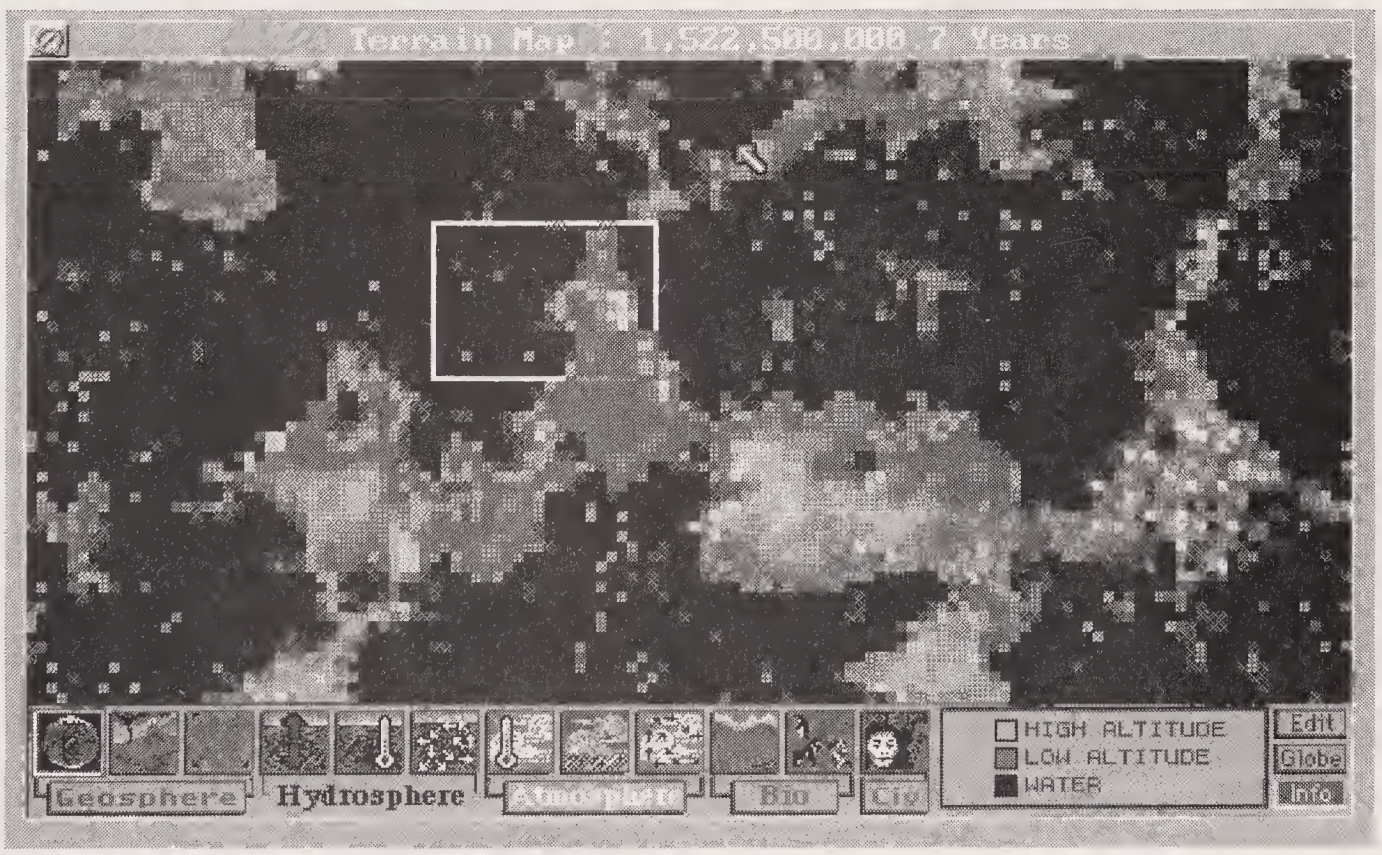
The Map Window gives you the overall view of your planet. In it you can view such diverse information as air and sea temperature, air, sea, and magma currents, rainfall, life, plant life, civilization, special events, and basic topology. You can see the map as a Cartesian (flat) map, or as a spinning globe, and you can also use the Map window to scroll through and choose an area to view in the Edit window. The Map and the Edit windows are the two most important windows in SimEarth.

Anatomy of a Map Window

Click on the Close box to close the Map window. (There's a mistake in the SimEarth manual that states this will close the Edit window. It's just a typo.) The Title Bar shows which type of map you are viewing and also the elapsed time of the simulation. You can move the Map window by clicking and dragging on the Title bar.

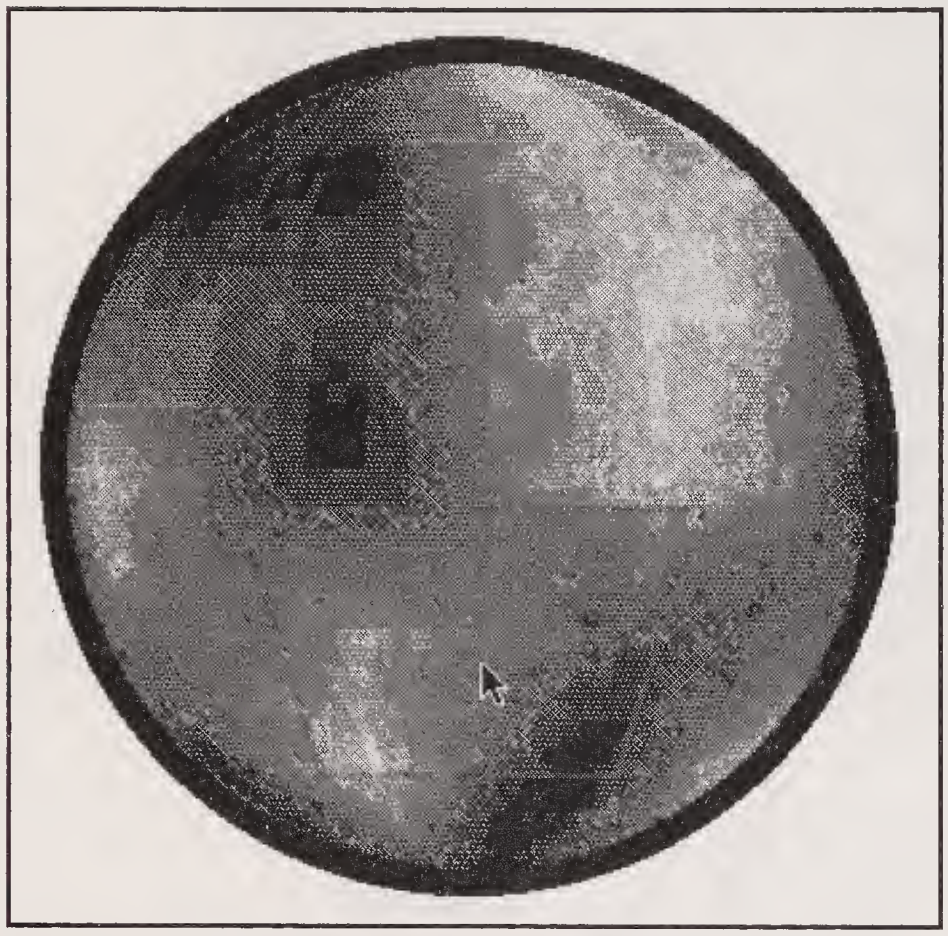
In addition to the standard Close Box and Title Bar, the Map window consists of several unique elements. In the



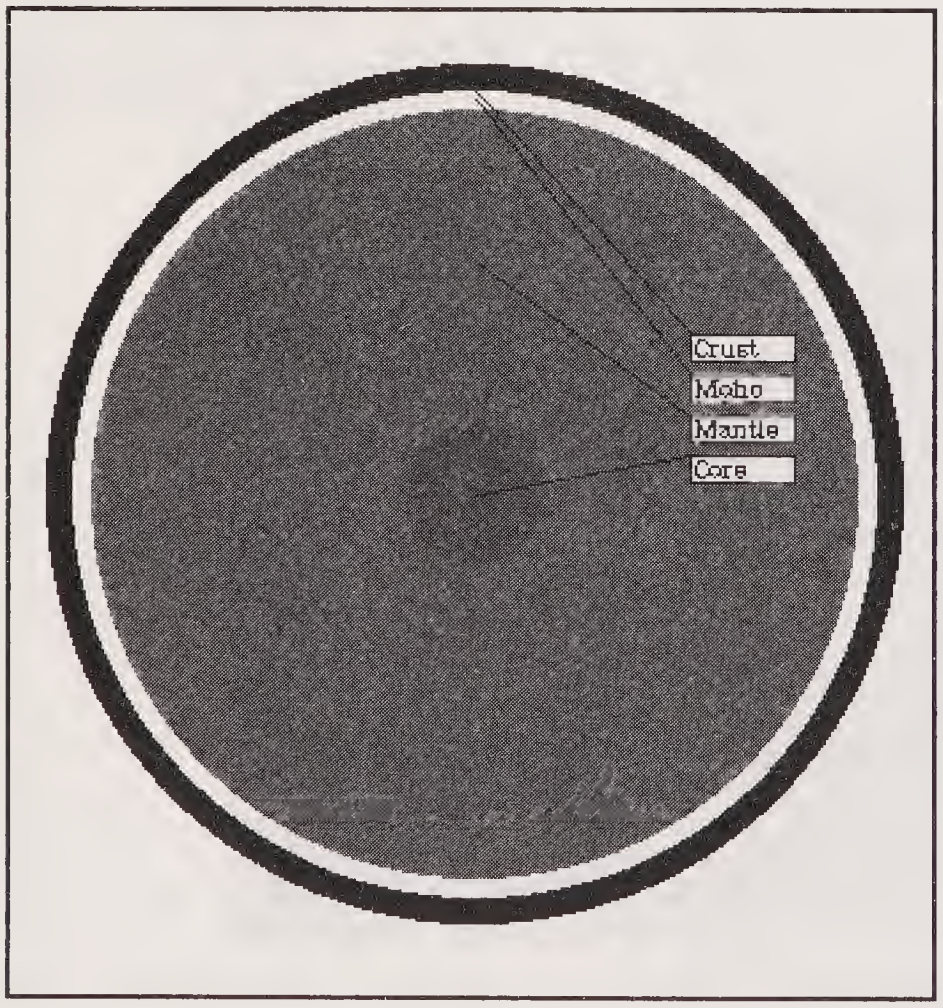


The IBM Map window is almost identical to the Macintosh Map window.

main Display Area, you see a map of the entire world laid out before you. The small rectangle that overlays the map's surface represents the area covered by the Edit window (whether that window is open or not). It's called (not surprisingly) the Edit Rectangle. Clicking and dragging the Edit Rectangle allows you to view other parts of the map in the Edit window. You'll notice that when you work with the Edit window, if you change the size of the Edit window, the Edit Rectangle changes size, too. That's because the Edit Rectangle is an accurate indicator of what is displayed in the Edit window.



Click on the GLOBE button to view the globe, then double-click to see the core.

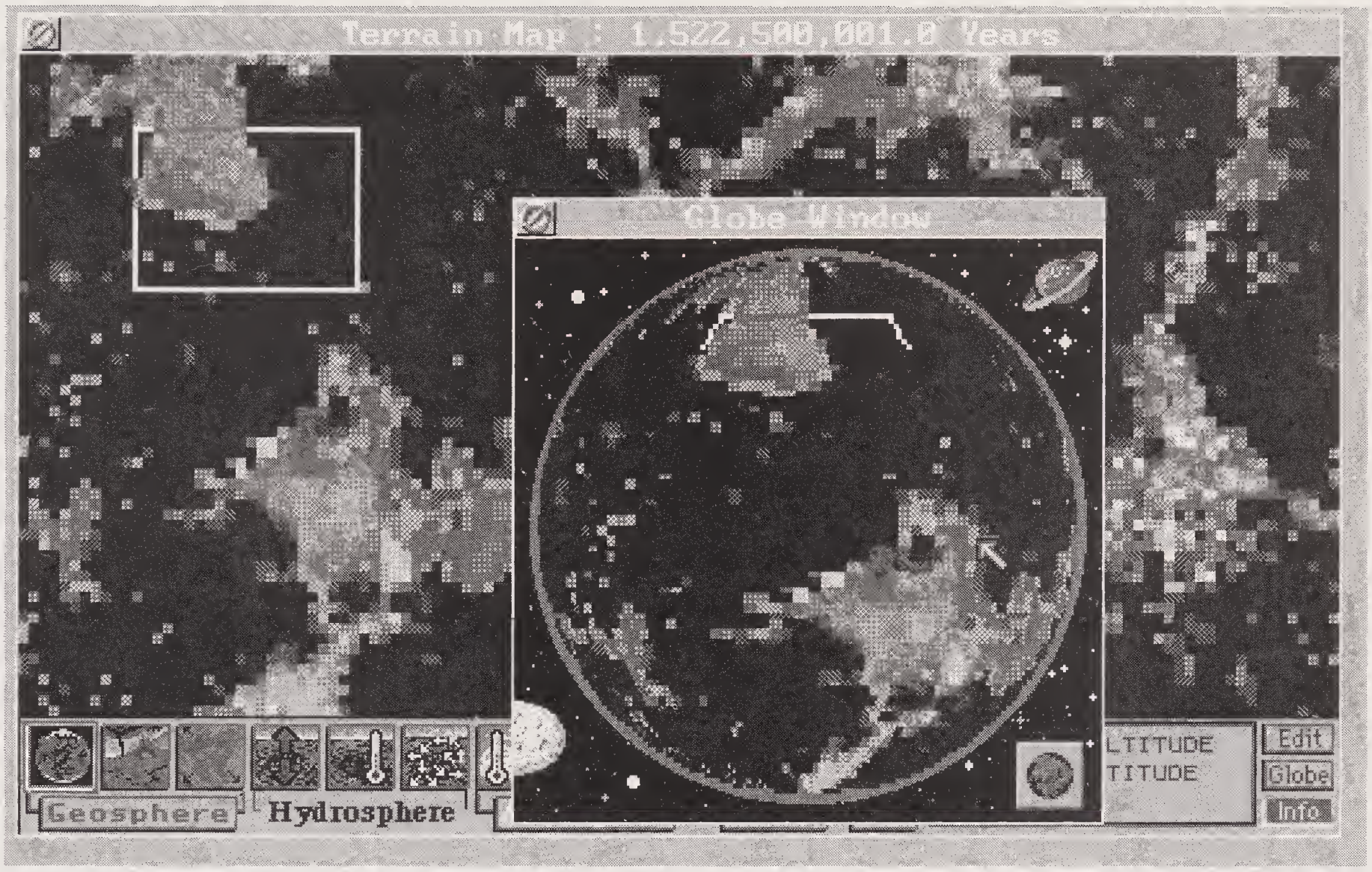


At the top of the Display Area is the Message bar. This is where SimEarth displays its one-liners—messages to help you know what is going on. For instance, if the heat is rising rapidly on your planet, the Message bar may inform you that the planet is overheating. If your civilization is in a Hellish state, the Message bar might let you know that, too. When you first start SimEarth, the Message bar informs you "No Game in Progress. Use 'New Planet' to Start."

The Spinning Globe

In addition to the flat Cartesian map of the world, SimEarth can display a spinning globe. In the bottom right section of the Map window is a small button titled "Globe." Click once on this icon to change the map to a globe. Click again to change back to a map.

When the globe is present, the Edit Rectangle becomes an Edit Trapezoid as it deforms in shape to accommodate the curvature of the planet. In addition, you can view the inside structure of the planet by double-clicking anywhere on the globe (except within the Edit Trapezoid). Like Superman, your X-ray vision will penetrate the surface and show the various zones of the interior. Click once to return to the currently activated exterior view.



The IBM Globe is a separate window. Click on the lower-right icon to open the control panel.

You can move the globe around by dragging on its outer border. All the Control Panel and Info Box buttons and icons are still active when the globe is present.

To stop the spinning of the globe, click once inside the Edit Trapezoid.

The Map Control Panel and the Info Box

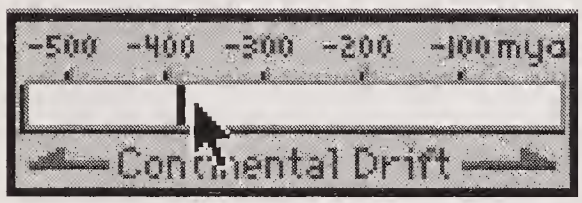
The Map window palette of icons along the bottom of the window is called the Map Control Panel. The Map Control Panel consists of five main group sections (consisting of four buttons and one label) and twelve palette icons. Each of the palette icons enables a different kind of display on the map.

To the far right of the Control Panel is the Info Box area which displays additional information, depending on which of the Control Panel icons has been selected. The specific information available is included in the description of each icon in the section that follows. Double-clicking in the Info Box brings up the History window.

In addition to the main Info Box information, there are three buttons in the lower right corner of the Map window.

- **Clicking on Edit opens the Edit window.**
- **Clicking on Globe turns the flat map into a spinning globe. Clicking on it again returns the flat map.**
- **Clicking on Info switches displays.**

Some icons only have one kind of display, in which case clicking Info will do nothing. Others have two displays—usually a legend and a graph—and clicking on Info will toggle between them.



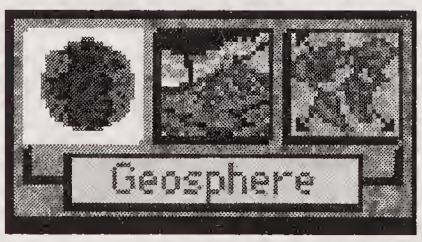
The Continental Drift Trick

Clicking and holding down the mouse button inside the Info Box triggers a special display of the continents in the Map window. Dragging side to side will then show the continental drift as it has occurred during the past 500 million years.

THE MAP CONTROL PANEL ICONS

The Map Control Panel Icons let you change the way the Map window appears, displaying alternate data like the ocean currents or the air temperature across the planet. There are five distict groups of icons: the Geosphere Group, the HydroSphere Group, the Atmosphere Group, the Biome Group, and the Civilization (Civ) Group.

At the end of each icon section, there is a definition of the icon's function as well as a section describing what is displayed in the Info Box and what happens if you double-click the icon.



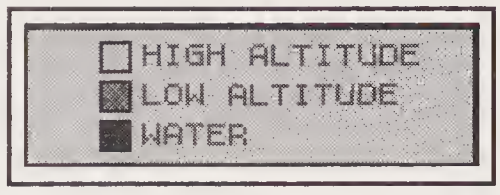
The Geosphere Group

The first section in the Control Panel is the Geosphere section. If you click on the Geosphere button (the one that says Geosphere), you'll open the Geosphere Model window. In the Geosphere Group, you can see a topological display of the planet's surface, see just the big events, or examine the direction of magma flow beneath the surface.

The Terrain Icon

Click on the Terrain icon to show the topological map in the Display area. This map shows the elevation of the planet with

darker squares representing lower elevations and lighter squares representing higher elevations. On color systems, water is blue. Otherwise it is represented by solid black.

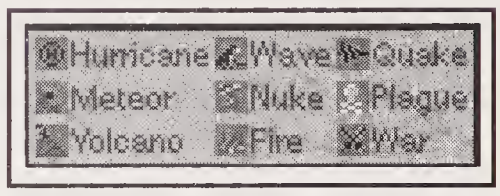


Info Box Displays: Legend only

Double Click: Gaia window

The Global Events Icon

Do you just like the excitement? The meteors? The hurricanes and tidal waves? Then the Global Events map is for you. Here, you'll dispense with any extraneous information and just watch the big events take place. The Global Events map displays all occurrences of hurricanes, meteor strikes, volcanoes, tidal waves, nuclear explosions, fires, earthquakes, wars, plagues, pollution, and Exodus departures.

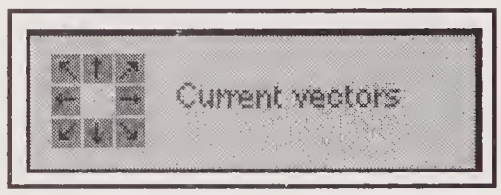


Info Box Displays: Legend only

Double Click: No effect

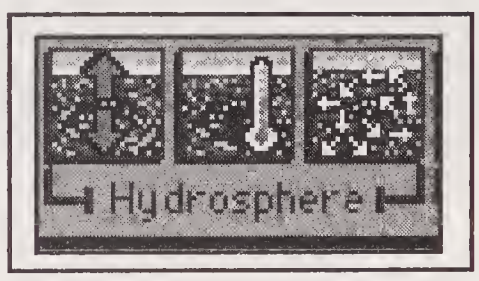
The Continental Drift Icon

This icon actually shows the direction of magma flow beneath the earth's crust. If you look at a place where the magma is pushing land masses into each other from opposite directions, you'll likely see a mountain range being formed. This is what is happening in the Himalayas as the Indian continent crashes into Asia. Another interaction may see one tectonic plate side-swiping another, scraping off land and causing earthquakes. This is essentially what is happening along the west coast of the United States with the famous San Andreas fault.



Info Box Displays: Vector legend

Double Click: No effect



The Hydrosphere Group

The second group of icons in the Control Panel governs the world of water. Here you can see the ocean temperature and

the direction of ocean currents. In addition, you can hide the ocean display to get a good look at the sea bed.

Clicking on the Hydrosphere label does nothing. You'll notice that, unlike the other four group names, it isn't a button, only a text label.

The Hide/Show Oceans Icon

Click on the Hide/Show Oceans icon to make the display of water on the planet disappear, exposing the terrain underneath. Click it again to replace the water. Although this has no effect on life or the evolution of the planet, it does allow you peek under the cover of the water to see the planet beneath it.

When you hide the oceans in the Map window, you can then click on any of the other icons in the Control Panel to view their information without the oceans present. When you hide oceans in the Map window, you also hide them in the Edit window. You can get an odd effect by clicking the Life button in the Edit window to display life with the ocean view turned off. The sea creatures will appear over the apparently dry surface.

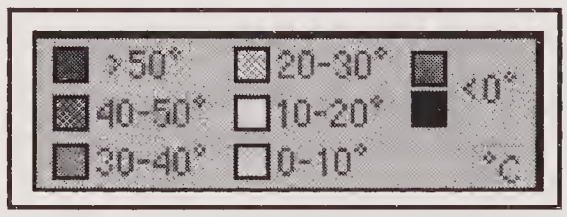
Info Box Displays: None

Double Click: No effect

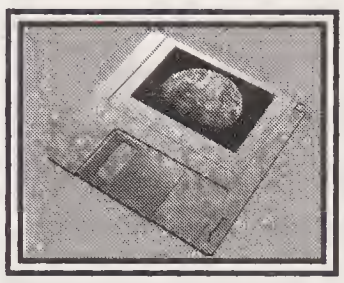
The Ocean Temperature Icon

Click the Ocean Temperature icon to display a graphical image of the annual average temperature of the oceans on your planet. Ocean temperatures will usually be very similar to air temperatures, but will change more slowly.

Info Box Displays: Legend and Graph of Temperature Over Time

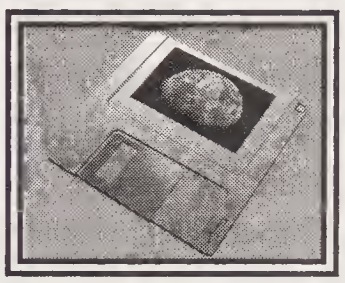


Double Click: No effect



How SimEarth Determines Ocean Temperature

The temperature of the oceans in SimEarth is determined by the Air/Sea transfer and by ocean currents moving water of different temperatures. Unless the setting for Air/Sea Transfer has been set very high, oceans tend to stabilize and keep temperatures more or less even. For instance, in any given area, if the ocean is hotter than the surrounding air, it will tend to give up some of its heat to the air resulting in hotter air and slightly colder water. Because of the vastness of the ocean, however, the average temperature changes slowly—much more slowly than the air temperature which can change quickly.

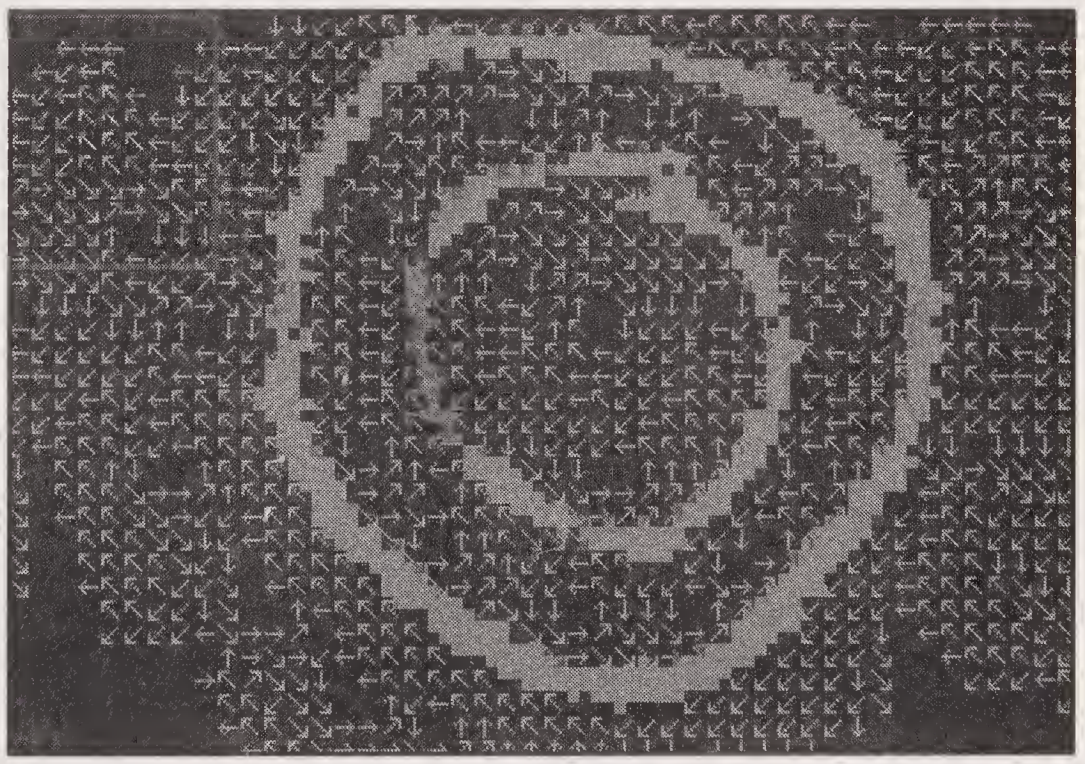


Ocean Currents in SimEarth

Ocean currents are extremely complex and any computer model which tried to reproduce them accurately would be huge and would have to run on one or more supercomputers. In order to simulate the flow of oceans in a program the size of SimEarth, a method had to be developed that did not require tens of thousands of lines of programming code and the processing power of a bank of Crays working together.

The system that resulted is both elegant and simple, yet it approximates pretty well the way the oceans move in the real world. Basically, each square or tile on the SimEarth map is a single area about 100 miles square. In the ocean, the water tends to try to stay at the same altitude. Therefore, if you were to create a long trench in the ocean, the water would tend to move along that trench, and water along the sides would move in their altitudes. In this way you might simulate an ocean current. However, the process isn't altogether that simple because the algorithm uses an average of the surrounding area to determine the altitude and the direction of movement.

A good example would be a dish-shaped depression. Water at the edges of the depression would tend to move around it in a circle while water at the bottom would tend to stay there. One other effect is that when the altitude is the same all around, the current tends to flow clockwise in the northern hemisphere; counter-clockwise in the south. When the water meets a continental boundary, it tends to go sideways toward the area closest to its current altitude.



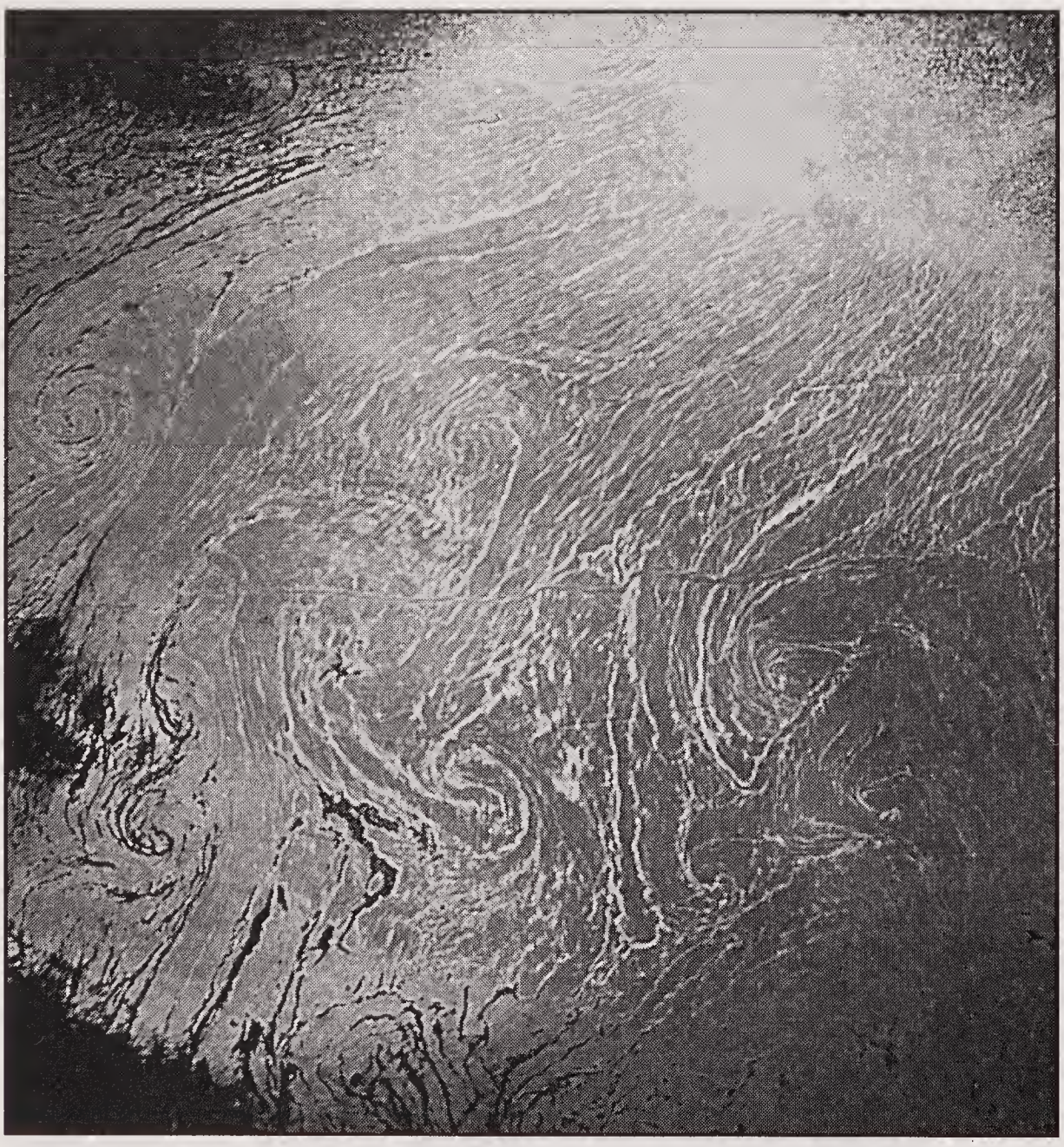
Here's a special Ring World showing ocean currents.

Earth's Ocean Currents

Man is always seeking mysteries to unravel, and the oceans hold their share. What at first we thought was just a giant body of water populated with fish and, perhaps, mythical creatures like the sailor's nightmare, the Kraken, we now know to be an integral and ever changing force for stability and change in the Gaian regulatory system.

It is the ocean with its vast and little understood circulation that helps keep the climate on Earth stable. Its vastness, covering about two-thirds of the planet, acts as a great stabilizer, and its abundant life and circulation system also help maintain the movement of nutrients and important chemicals like iodine, for instance, from land to sea. In fact, the miracles of the ocean never cease to amaze us, and its importance to our well being can't be overstated.

Early sailors learned to recognize the great currents in the ocean and use them to advantage. But these ocean rivers serve more than man's need for speedy sailing. They help regulate the climate on the planet. In some ways, the ocean currents are like the circulatory system of the planet. If one of the great currents, like the Atlantic Gulf Stream or the Kiroshio current that travels from Japan to the west coast of the U.S., were to change course, the climates in places like New York or Seattle would undergo dramatic transformations, and it's doubtful that many people would enjoy the change.



In this image, you can see ships' wakes crossing the spiral eddies in the ocean.

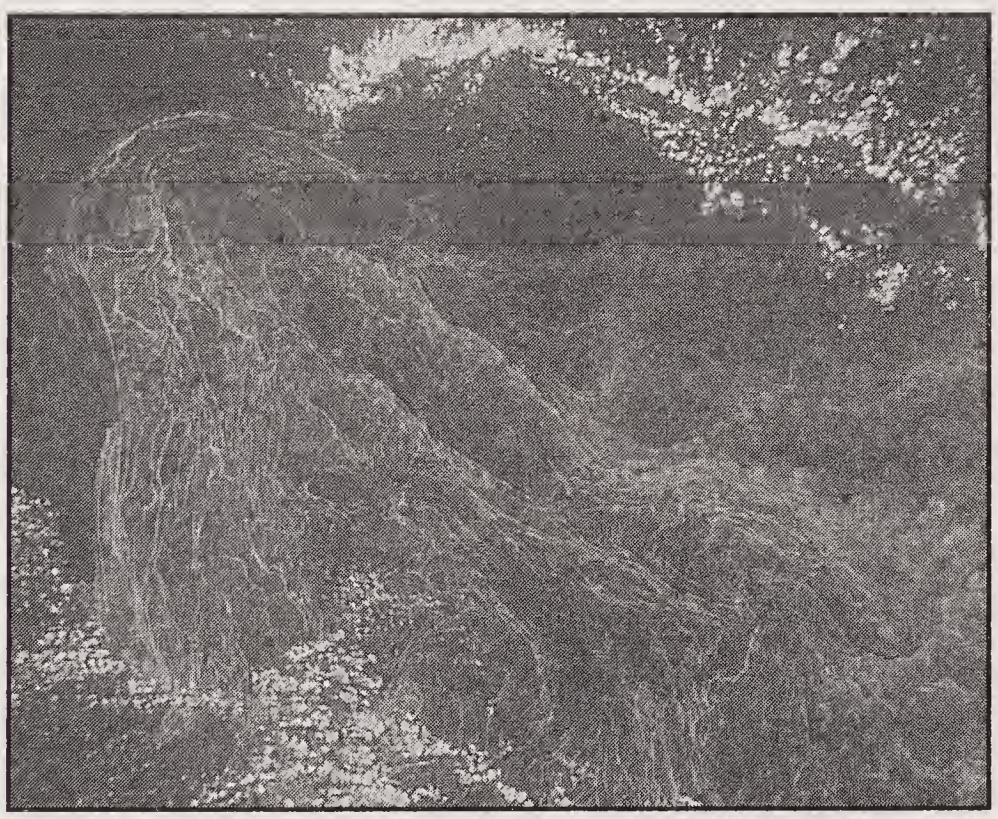
In addition to the many currents (or, more properly, gyres) that exist everywhere in the oceans, there are other effects. Recently scientists have discovered vast rings which spin off the main currents, carrying warmer water out into the cold ocean (and incidentally becoming either a great aid or an obstacle to avoid for boats in the area, depending on which part of the ring they come into contact with).

But there are other, more subtle currents in the oceans, currents buried deep beneath

the surface. These currents originate at the poles, where the water is not only colder, but saltier since all the icebergs and ice caps are pure water, and in their formation, salt was left behind in the water that remained liquid. This colder water sinks and begins a journey that may take centuries, a journey toward the equator. Remarkably, the oceans are layered. Although to our eyes most water looks alike, the water migrating from the poles does not mix with the water at the surface. In fact, scientists have discovered that many distinct layers exist in the ocean depths, and each, like a page in a book, remains distinct under normal conditions. Slowly the migrating polar water will warm and rise and join the flows and currents of the surface. And of course new, warmer currents move toward the poles. In this way, the waters of the ocean slowly turn over.

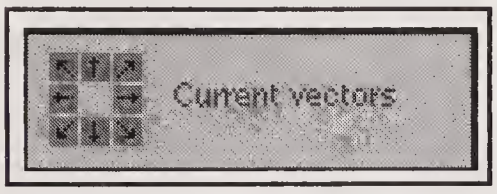
Even more dramatic and important from our perspective are the so-called upwellings. Upwellings occur when the deep waters at the bottom of the ocean rise to the surface, often precipitated by offshore winds. They invariably carry with them a soup of nutrients and the combination of this rich soup with the abundant sunlight at the surface causes great blooms of phytoplankton, perhaps the most important "crop" of the ocean's vast bounty. It is these plankton that form the base of the food chain that eventually feeds all life in the oceans. Feeding off the phytoplankton are other tiny creatures, the zooplankton which in turn are consumed by creatures ranging from squid and jellyfish to herring, anchovies, and even baleen whales. In fact, anything that threatens the plankton blooms threatens almost all life in the oceans one way or another.

This image shows standing waves at the western approach to the Strait of Gibraltar. It also shows semi-diurnal internal waves caused by the tides. These internal waves are moving eastward into the Mediterranean Sea.



Part of a phytoplankton bloom stretching nearly 200 km. This one is only 20 cm. thick, but some can be up to 5 meters thick.

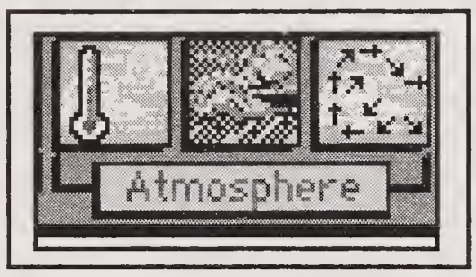
The Ocean Currents Icon



Click the Ocean Currents icon to display surface currents in the oceans.

Info Box Displays: Vector legend

Double Click: No effect

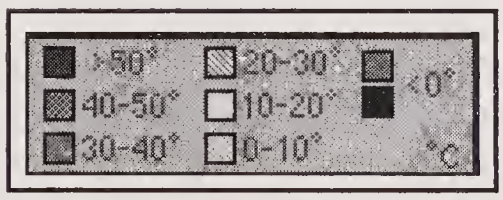


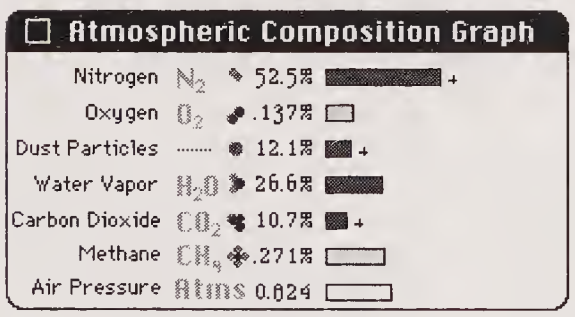
THE ATMOSPHERE GROUP

Clicking on the Atmosphere button displays the Atmosphere Model window. The Atmosphere Group consists of three icons: The Air Temperature Icon, the Rainfall icon, and the Air Currents icon.

The Air Temperature Icon

To see the average annual air temperature, click on the Air Temperature icon. Air temperature in SimEarth is mostly determined by solar radiation, though some escaping heat is reflected back into the atmosphere and warms the air still more due to the greenhouse effect. Also, there is some transfer of heat between the oceans and the air which you can affect in the Atmosphere Model Control Panel setting called Air/Sea Transfer. The temperature of the water has a buffering effect on the air temperature which tends to stabilize it over time.





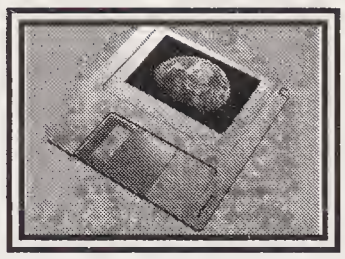
Info Box Display: Legend and Graph Over Time

Double Click: Atmospheric Composition Graph

The Rainfall Icon

To see the average annual rainfall over the planet, click on the Rainfall icon. Rainfall is influenced by several factors. The main factor affecting rainfall is the amount of water vapor in the air. Other factors include the amount of CO_2 in the air and the amount of cloud cover.

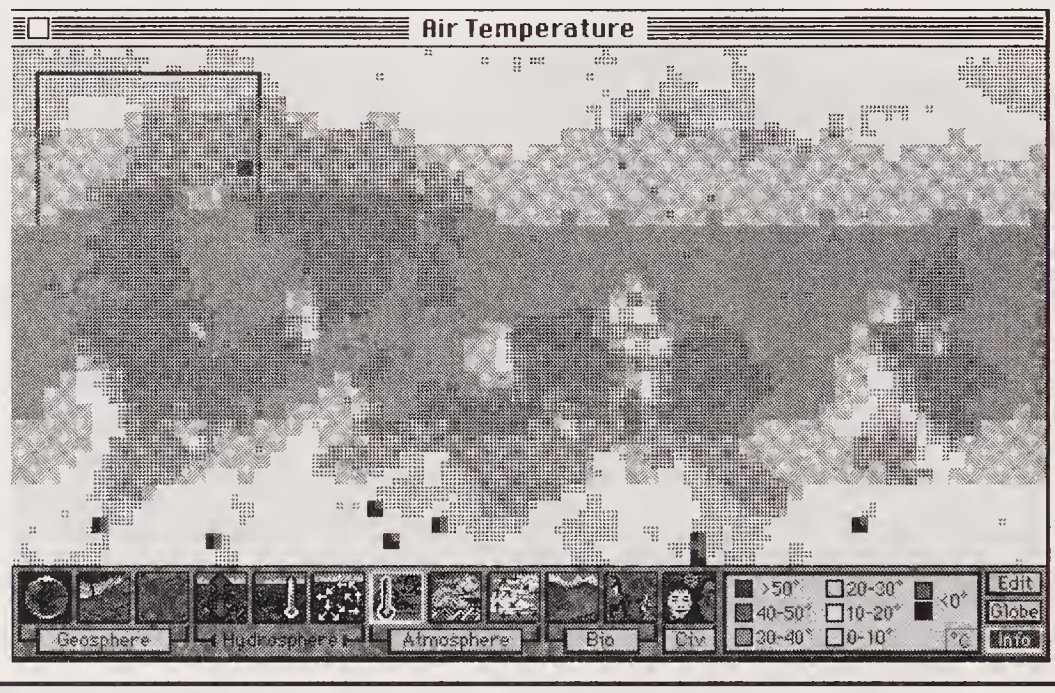
Water vapor is affected by such diverse events as hurricanes and meteor strikes in the ocean. Green biomes like

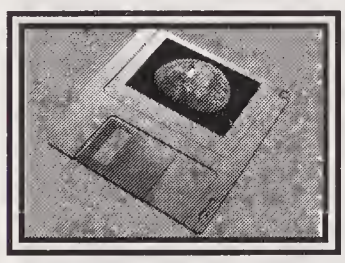


Atmospheric Temperature in SimEarth

In SimEarth, air temperature is modeled by a complex set of conditions which combine the amount of solar output, local cloud cover, the albedo of the surface and of the clouds, the current air temperature at the spot being measured, the current altitude, the current latitude (the sun being more intense near the equator), and, finally, the greenhouse effect. Since all these conditions are used to determine any local air temperature, it is difficult to predict exact temperature in a single location. As in real life, most local conditions are dependent on forces that range from the nearby conditions to events that may occur thousands of miles away.

One of the most interesting theories is explored in detail in James Gleick's book Chaos. Although it is an oversimplification of the situation, part of Gleick's book deals with a phenomenon called The Butterfly Effect. In essence, it is an attempt to explain both the incredible complexity, and also the incredible interconnection of certain systems, weather and climate among them. The Butterfly Effect states, in Gleick's words, that "a butterfly stirring the air today in Peking can transform storm systems next month in New York." Nothing is insignificant. Everything is connected. And given that, our ability to predict weather, climate, or our own futures is probably doomed to hazy, short-term guesses at best.





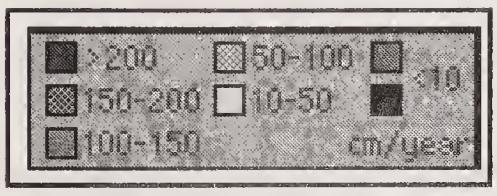
The Rainfall Model

Basically, in SimEarth there is one layer that represents both clouds and rainfall. Rainfall is affected in the model by several factors. If there are clouds over water and the temperature is at a certain level, rainfall is likely. Depending on air currents, rainfall will be blown inland. In order to simulate the effect of the rain shadow found on mountain ranges, rain tends to fall as altitude increases. This means that if clouds are blown by prevailing winds toward areas of high altitude (mountains), they will tend to drop rain. The SimEarth model also takes into account a real effect found on Earth where rainfall also seems to depend on the latitude. So-called Halley cell regions between 20 and 30 degrees around the equator tend to be much drier. The effects can be seen on a globe by examining such areas in those latitudes as Mexico and North Africa. SimEarth takes into account the Halley cell effect as well.

the tropical rainforests send more water vapor into the air as well.

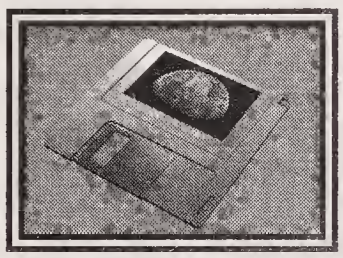
All things being equal, lower carbon dioxide levels in the atmosphere will lead to drier conditions.

You can affect Rainfall directly by changing the Rainfall setting in the Atmosphere Model Control Panel, or more indirectly by changing the setting for Cloud Formation on the same control panel.



Info Box Displays: Legend and Graph Over Time

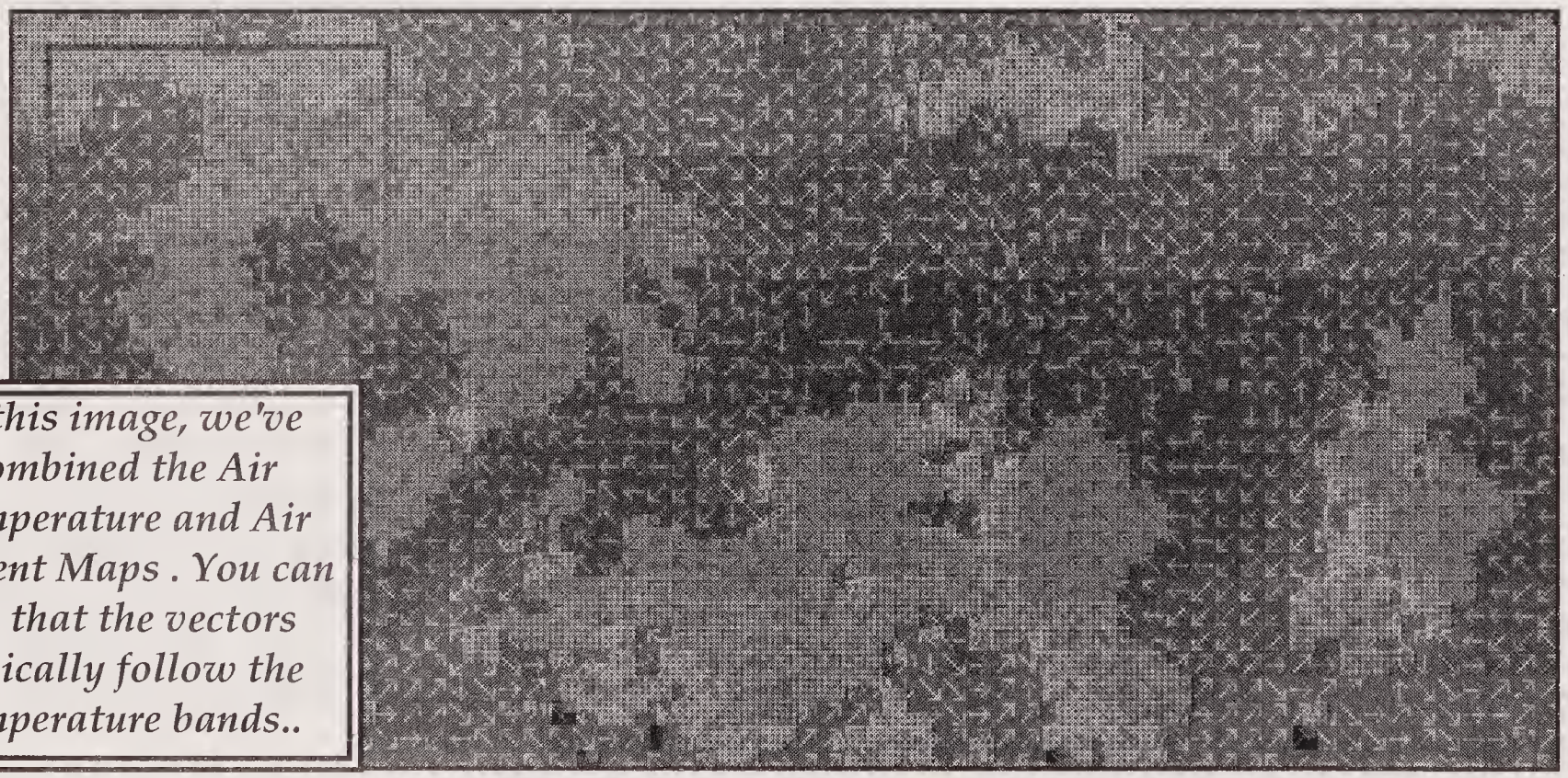
Double Click: Atmospheric Composition Graph



Air Currents

SimEarth handles air currents in a fairly simplistic way. Basically, air vectors tend to move toward similar temperature zones. If you turn on the Air Temperature Map, you'll see the bands of temperature represented by shaded squares. In all likelihood, the air current vectors will tend, more or less, to follow these bands.

What makes the air current model actually work, however, is that it is derivative of the air temperature model which is much more complex. In combination with the air temperature model, such natural effects as the jet stream are simulated fairly accurately. For more information on that model, see the sidebar on the air temperature model.



In this image, we've combined the Air Temperature and Air Current Maps . You can see that the vectors basically follow the temperature bands..

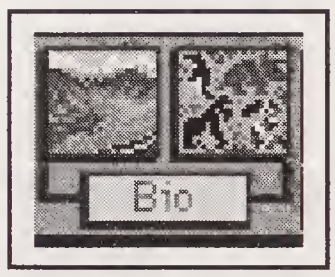
The Air Currents Icon

To see basic wind patterns in the atmosphere of your planet, click on the Air Currents icon. Air currents are caused by the differences of air temperature and pressure as well as by the Coriolis effect caused by the spinning of the planet.

Info Box Displays: Vector Legend

Double Click: Atmospheric Composition Graph

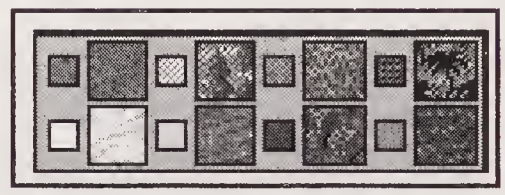
The Biosphere Group

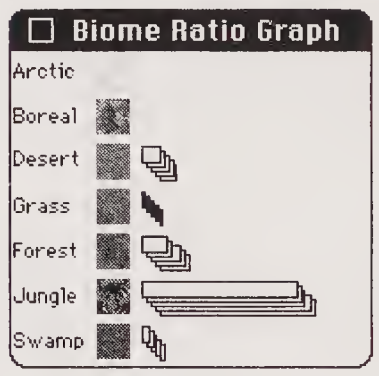


Clicking on the Bio button will display the Biosphere Model window. There are two icons in the Biosphere Group: Biomes and Life.

The Biomes Icon

To see the basic distribution of plant life on the planet, click on the Biomes icon. In addition to showing the distributions of forests, deserts, and other biomes, this is a good view to use to watch the overall climatic effects of the planet. If you are entering an ice age, this view will show the effects quickly, both in the changing biome patterns and also in the growth of polar ice caps.



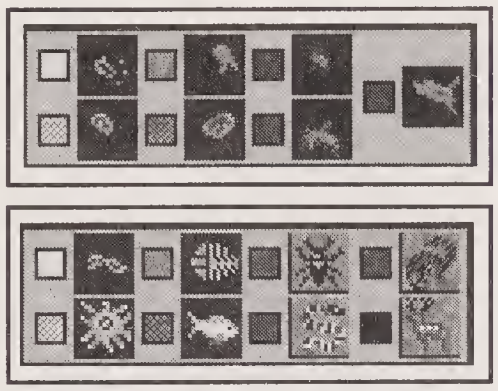


Info Box Displays: Biomes Legend and Graph of Biomass Over Time

Double Click: Biome Ratio Graph

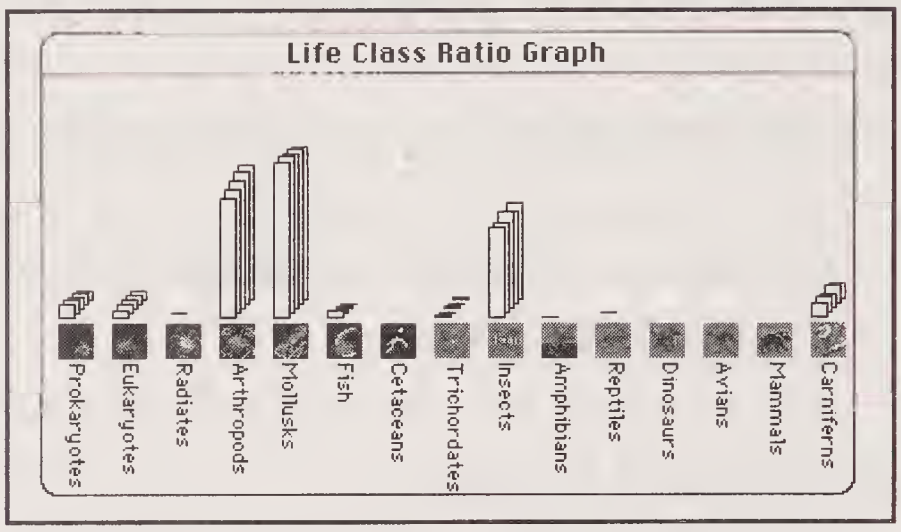
The Life Icon

To see the diverse non-sentient life of your planet, click on the Life icon. This will show all animal life as it appears on the planet's surface, on land and in the oceans. In a well-developed world, this map will be covered with creature icons.



Info Box Displays: Life Legend and Diversity Graph Over Time

Double Click: Life Class Ratio Graph



THE CIVILIZATION GROUP

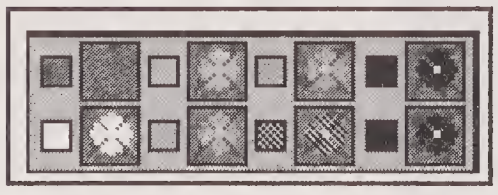
Once a species has reached sentience, SimEarth enters the civilization time period. Click on the Civilization button to view the Civilization Model window. There is only one icon in this group—the Civ icon.

The Civ Icon

To see only the cities of your civilized people, click on the Civ icon. Each city will show up as a small square on the map, color coded (or shaded) by level of advancement.

Info Box Displays: Civilization Legend and Population Graph Over Time

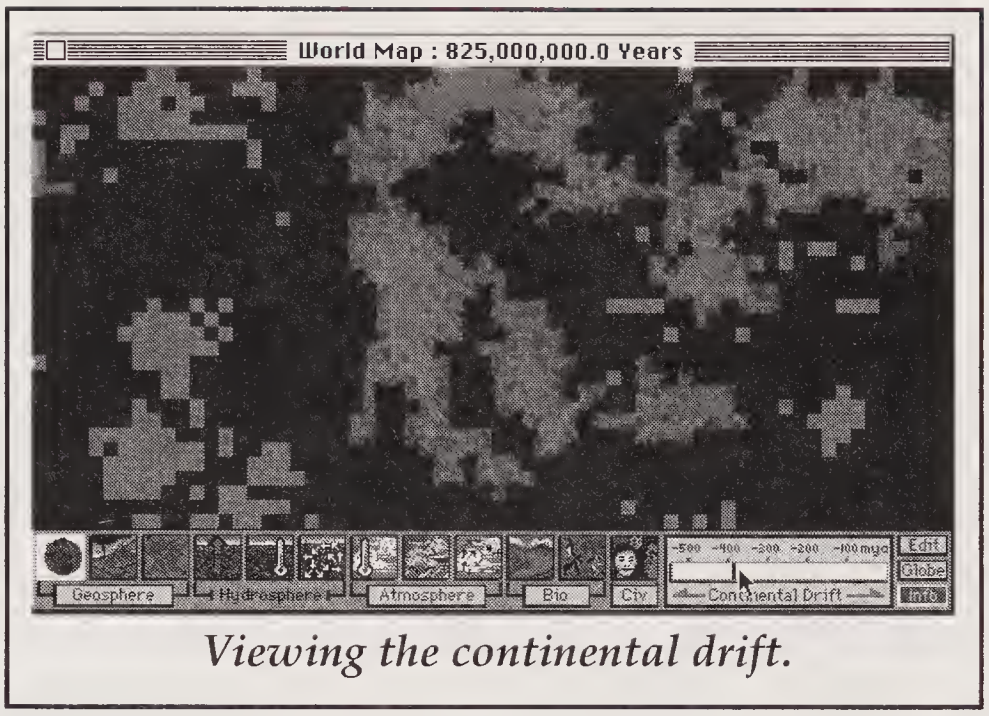
Double Click: Technology Ratio Graph



SPECIAL INFO BOXES:

Daisyworld Info box shows a legend of different colored daisies.

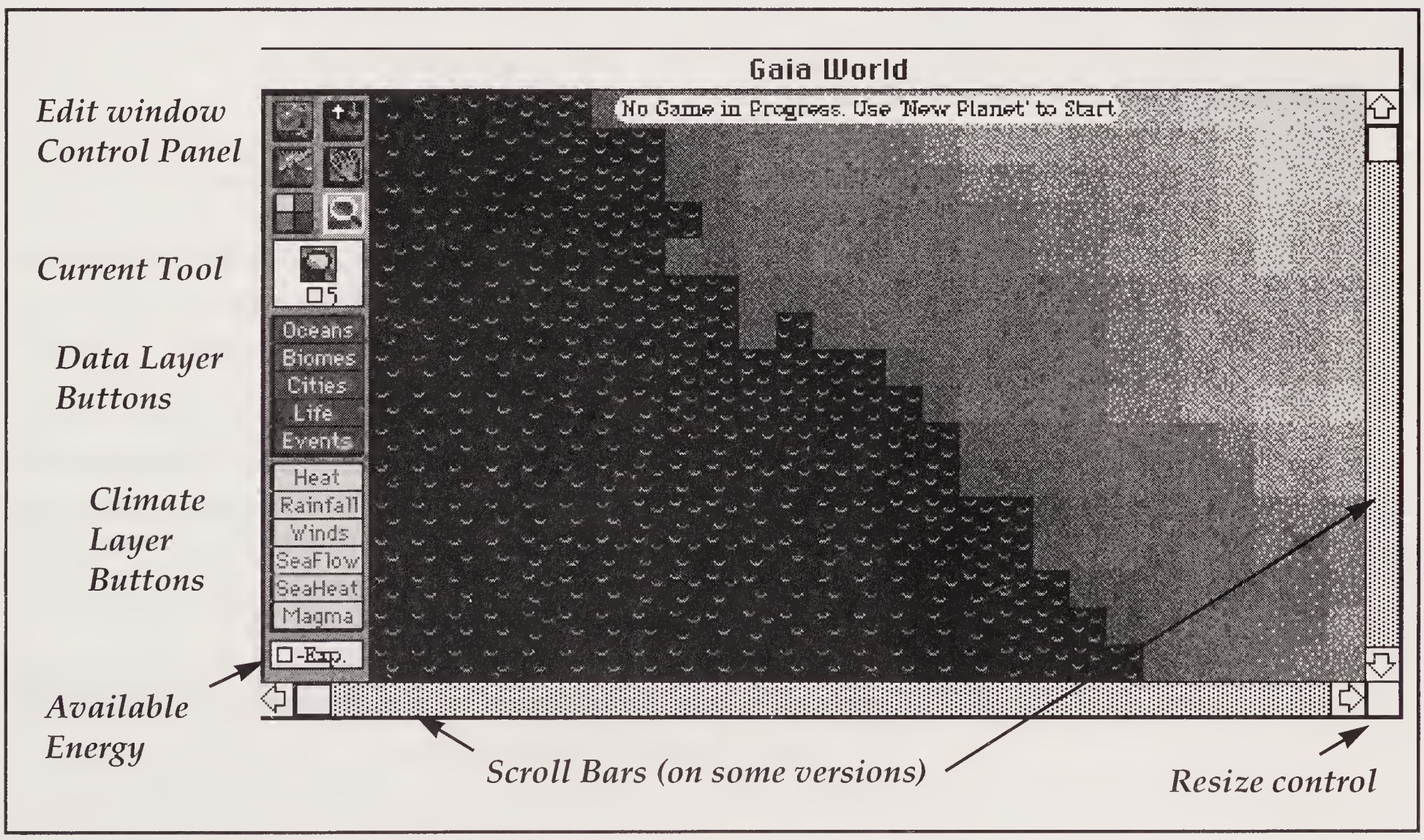
As noted above, a record of Continental Drift can be seen graphically by clicking and holding in the Info box and then dragging right and left.



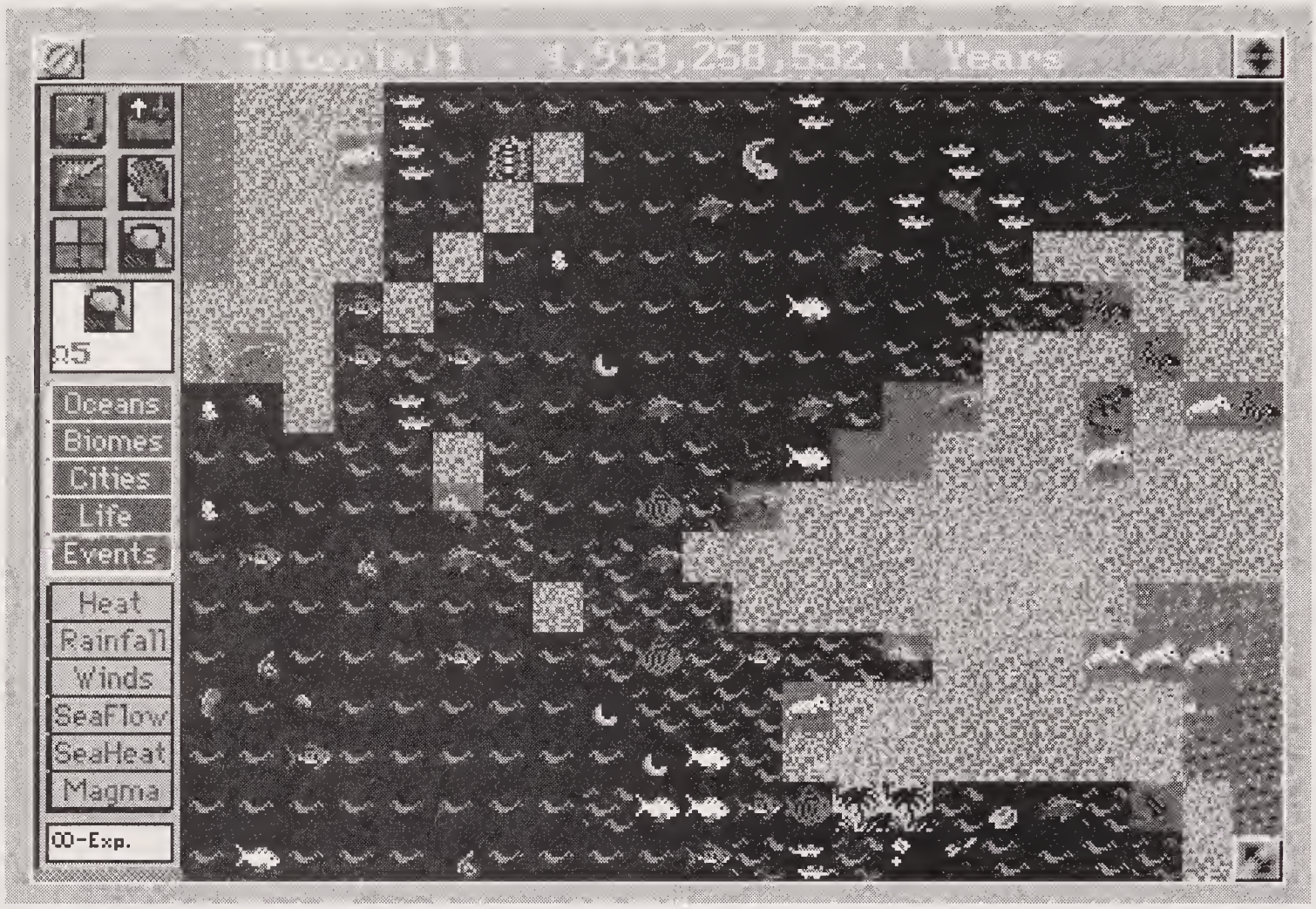
Viewing the continental drift.

THE EDIT WINDOW

The Edit window is one of the main places where you can directly affect the planetary simulation. (The other place is in the Model control panels.) Here you can place life, cause disasters, place biomes, raise and lower land, and even move things around on the planet's surface. In addition, you can get a closer look at the various areas on the planet.



The IBM Edit window has no scroll bars. Move the cursor to the edge of the box to move the view. Both windows have Close boxes and Zoom boxes (to make the window full screen size). Controls are all the same.



Edit windows for Mac (previous page) and IBM (above).

The Edit window has several common structural elements like the Close box and the Title bar. It, like the Map window, also has a Message bar where occasional messages will appear.

One interesting feature of the Edit window is the Grow box (or Zoom box) which lets you alternate between a full-screen sized Edit window, and a smaller one. In addition, dragging the lower right corner of the Edit window lets you change its size. For more specific information, check the diagram for your computer type, since some specific structural elements may vary.

In addition to the basic structures, the Edit window has a Display Area and a Control Panel (like the Map window, but with different icons and buttons). The Edit window Control Panel contains six active icons and eleven buttons divided into two groups—the Data Layer buttons and the Climate Overlay buttons.

The Control Panel also displays certain useful information including the current tool in use and the amount of energy units (EU) remaining.

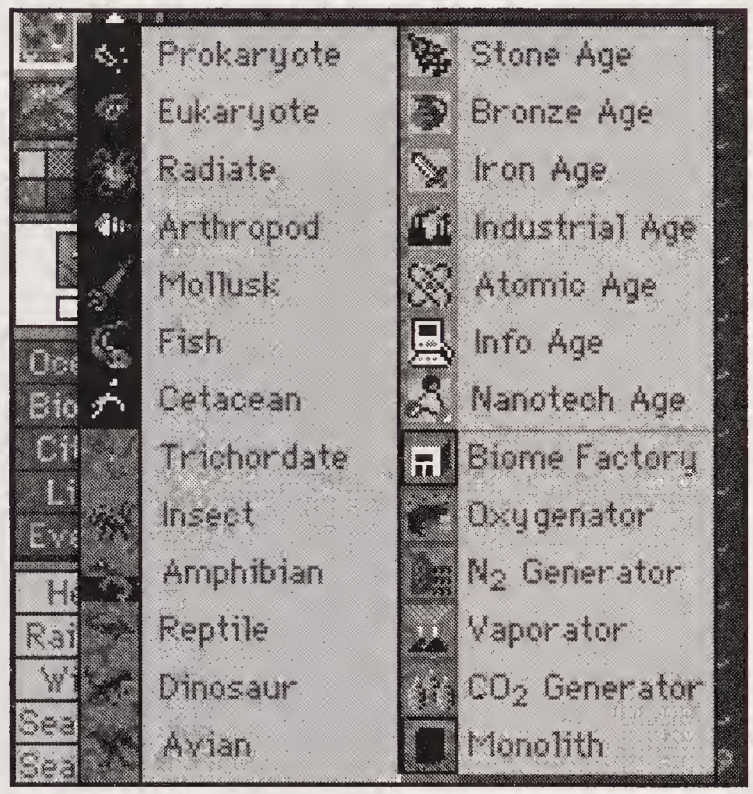
The six Tool Icons can perform a lot of useful tasks. These are the main tools you'll use to manipulate the model directly (other than the settings you change in the Model control panels).

EDIT WINDOW CONTROL PANEL

TOOL ICONS

The Place Life Tool

Whenever you want to place a living creature or a city directly on your world, you'll use the Place Life tool. In addition, Place Life lets you work with some unusual bonus items like the nanotech-level gas and biome generators, the monolith, and ice meteors.



You can place anything from single-celled life (prokaryotes and eukaryotes) to whole cities. Simply click on the Place Life tool, hold down and scroll over to the choice you want. Then release the mouse. IBM PC compatible users can simply click on Place Life, then select the item they want by clicking again because the sub-window stays open after you click the Place Life tool.

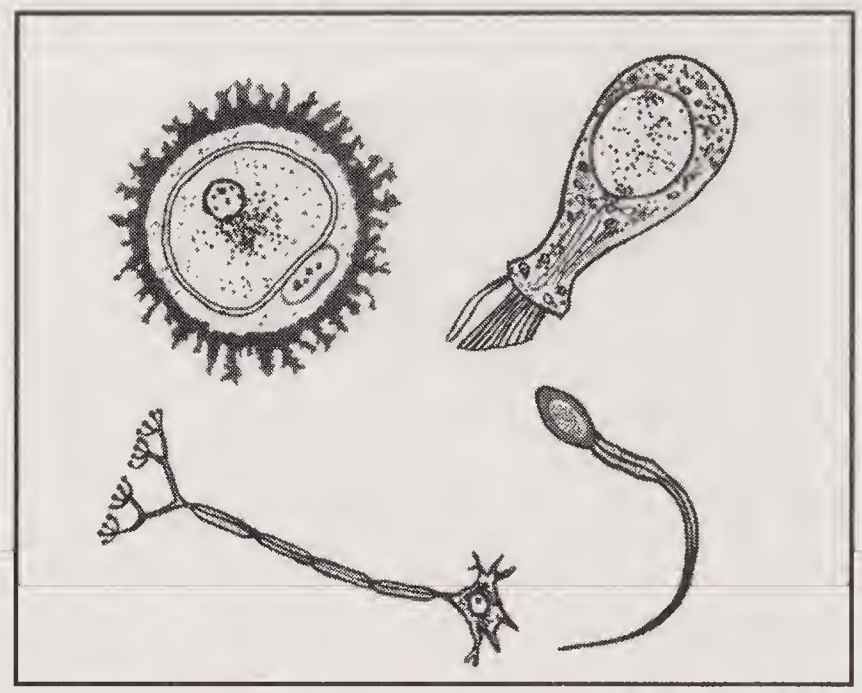
Each life form "costs" a certain amount of energy to place. If you are using a limited energy scenario, you'll have to watch your expenses. In the Experimental (unlimited energy) mode, you can place anything you want, whenever you want. It may not survive, though. For instance, putting a fish on land (a fish out of water) will probably not work (unless, perhaps, there's an invisible river there...).

Also, you'll notice that some items aren't allowed in a particular time scale. For instance, you can't just drop a nanotech city in the Evolution Time Scale, before intelligent life has evolved. Nor can you drop a mammal in the geologic time scale before multicellular life has formed. However, you can drop a mammal on the land right after the Cambrian period, millions of years before it would have evolved naturally. This is one way to influence which species evolves to intelligence first, but it doesn't guarantee success.

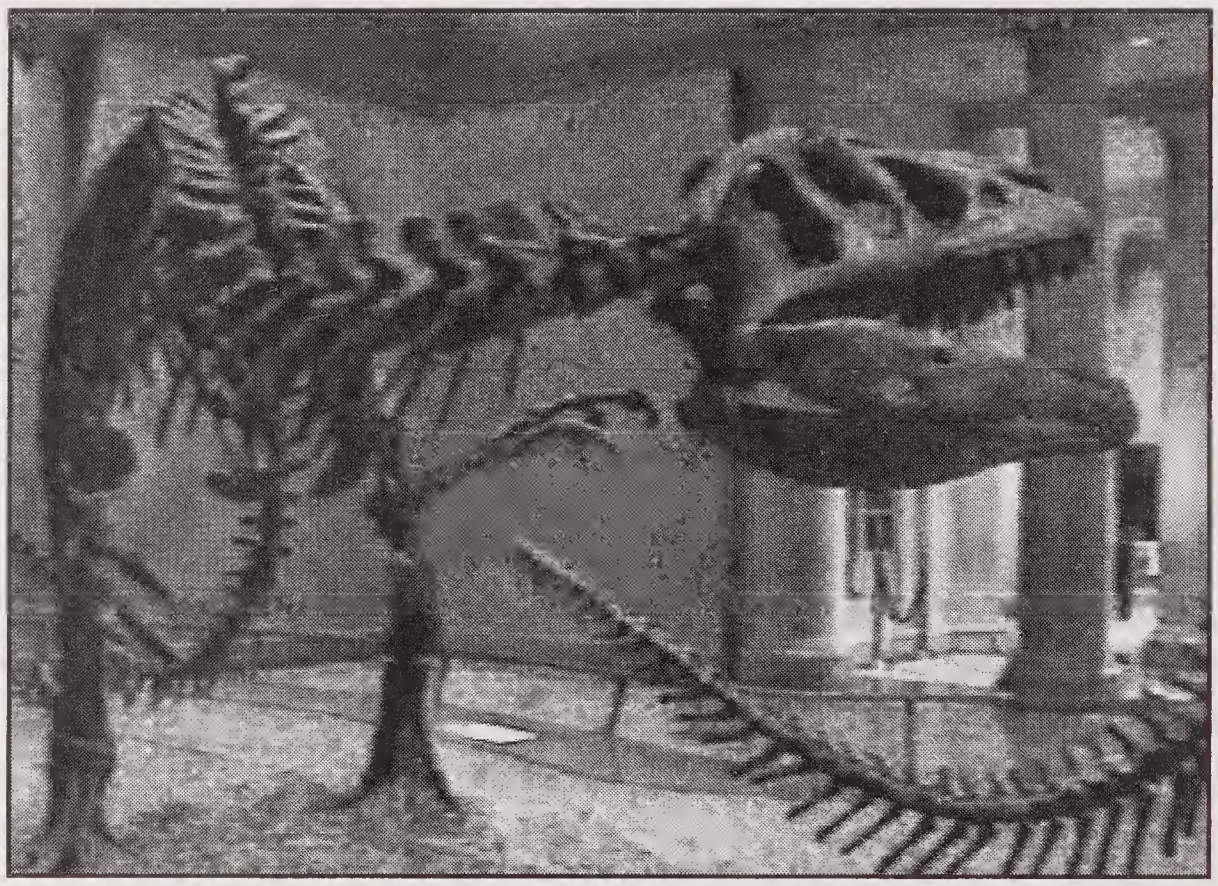
Extincting a Species

From the god-like perspective of SimEarth, you have considerable power. One of your more awesome abilities

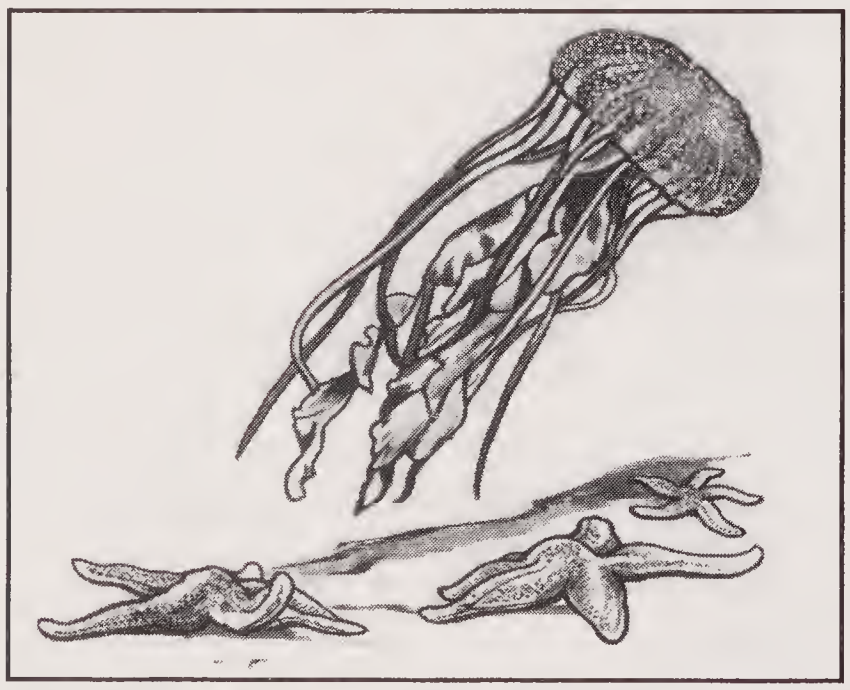
Prokaryotes



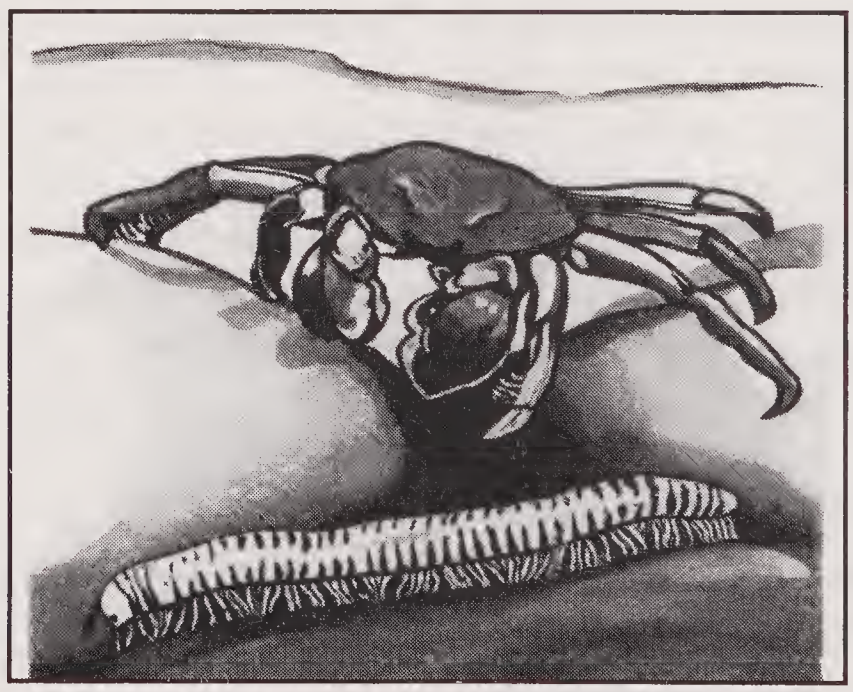
Eukaryotes



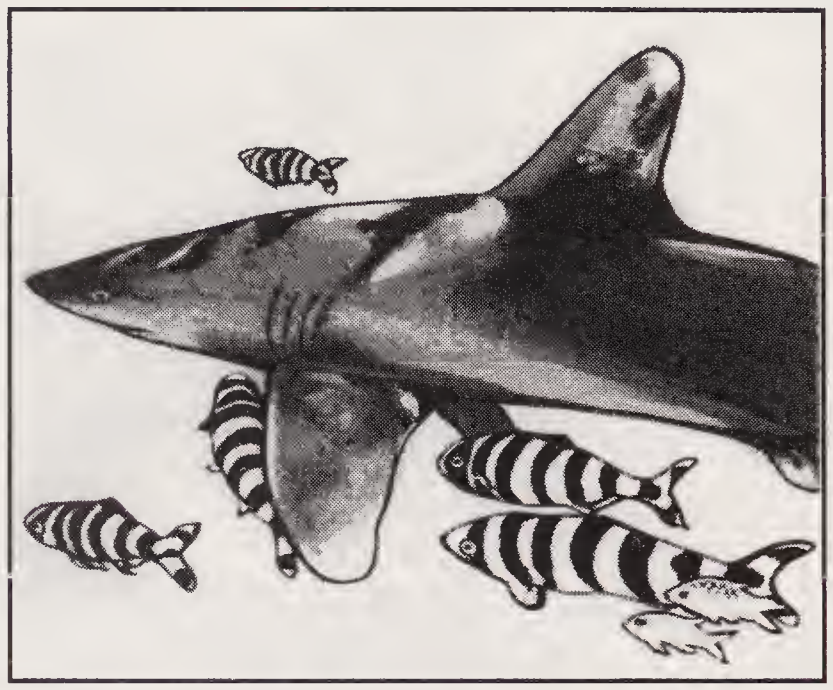
Radiates



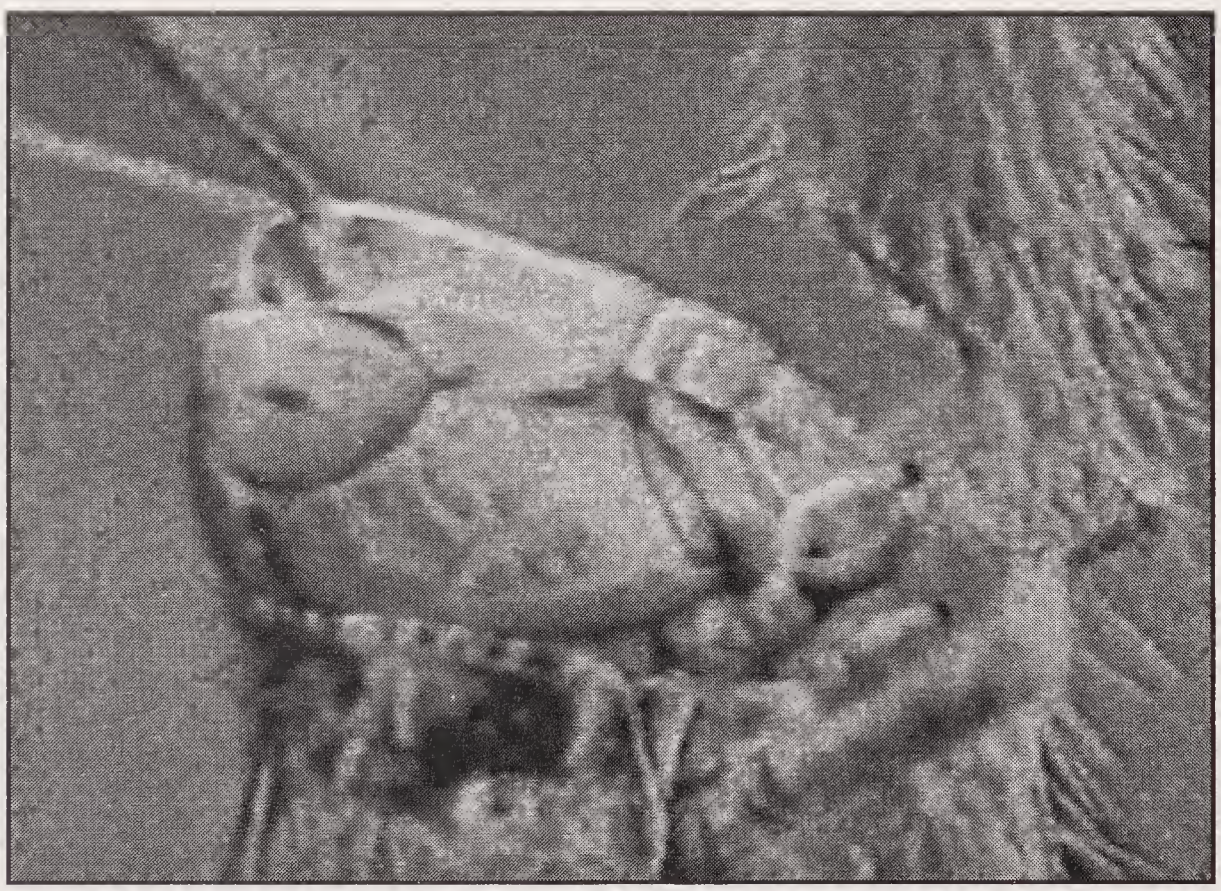
Arthropods



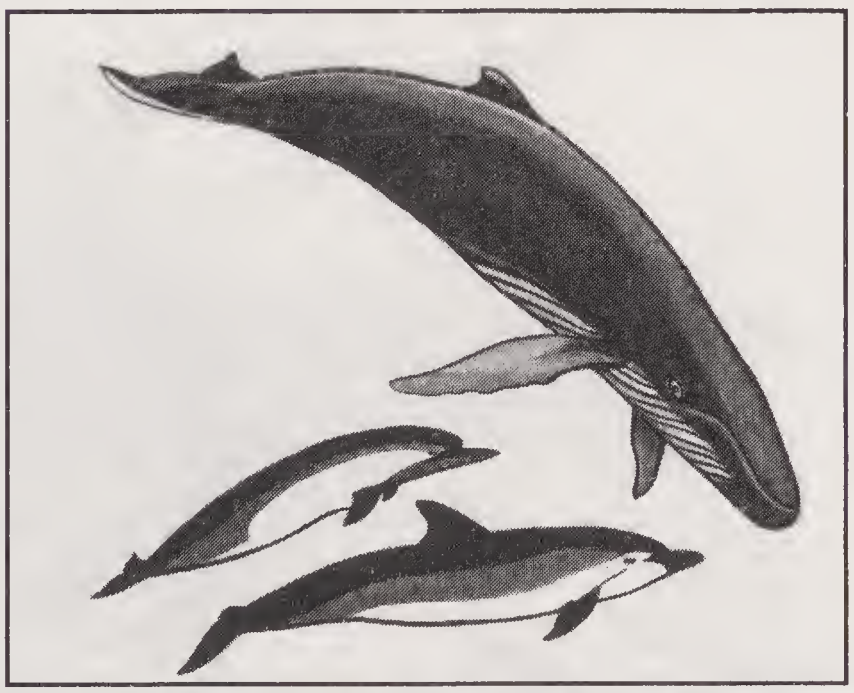
Mollusks



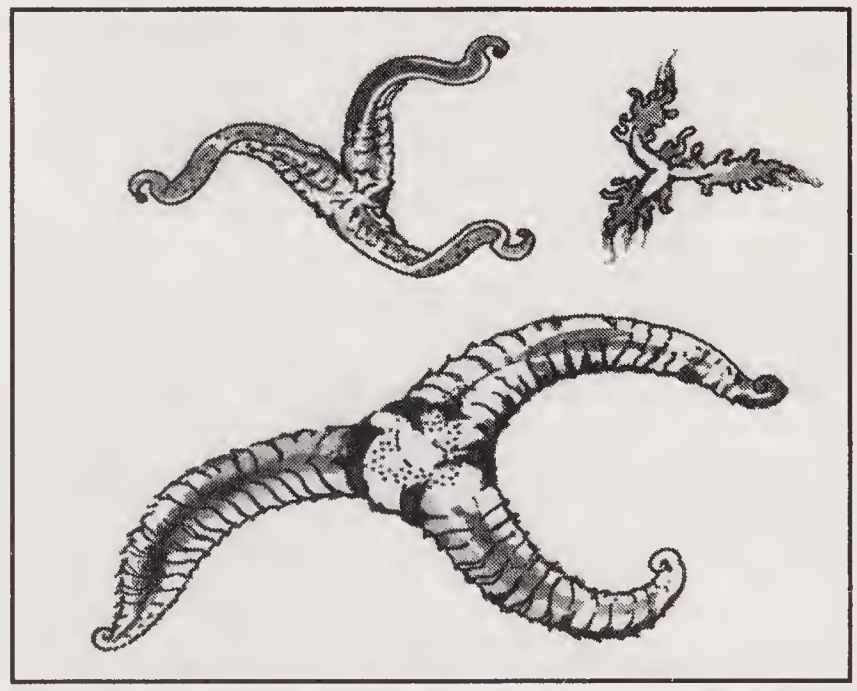
Fish



Cetaceans



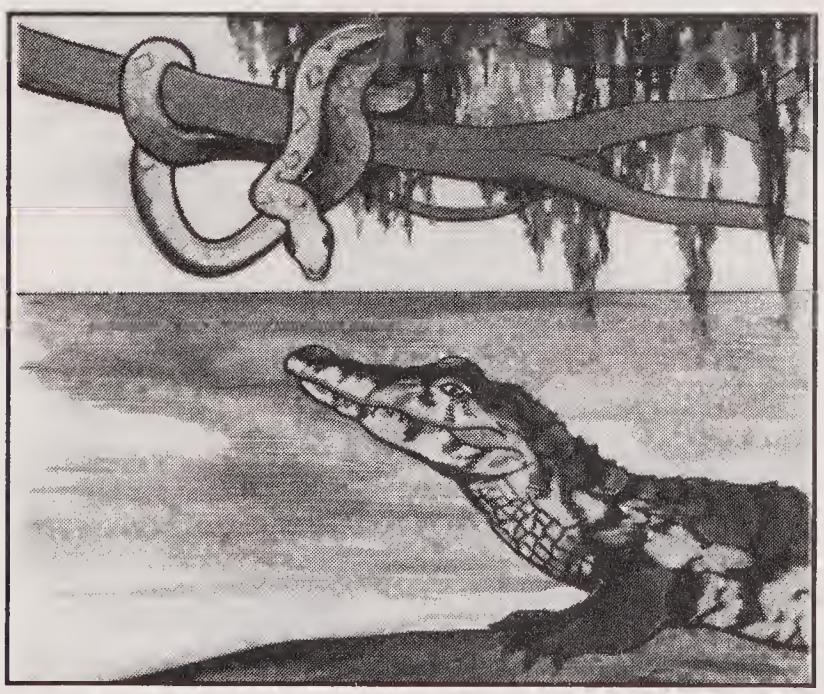
Trichordates



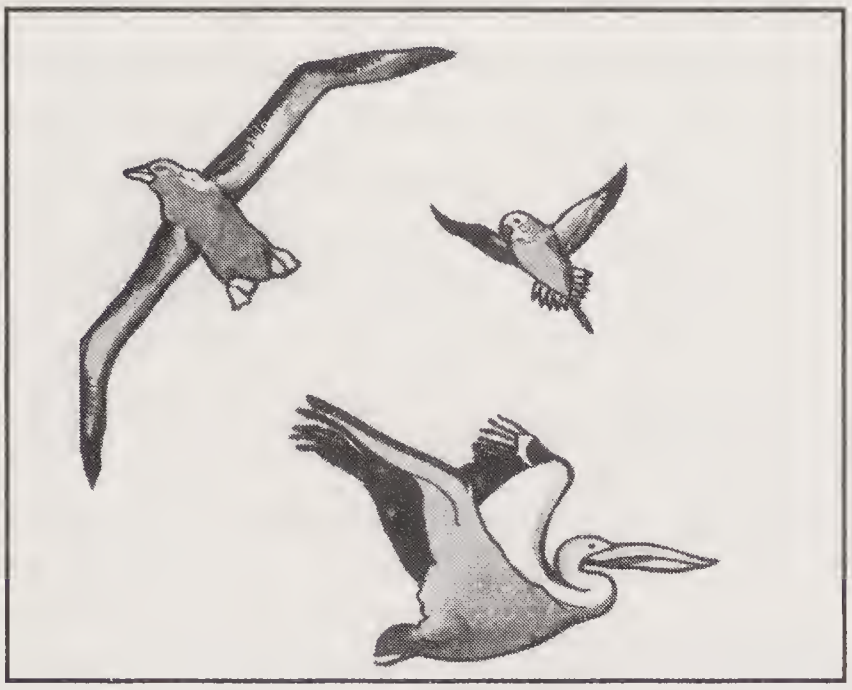
Insects

Amphibians

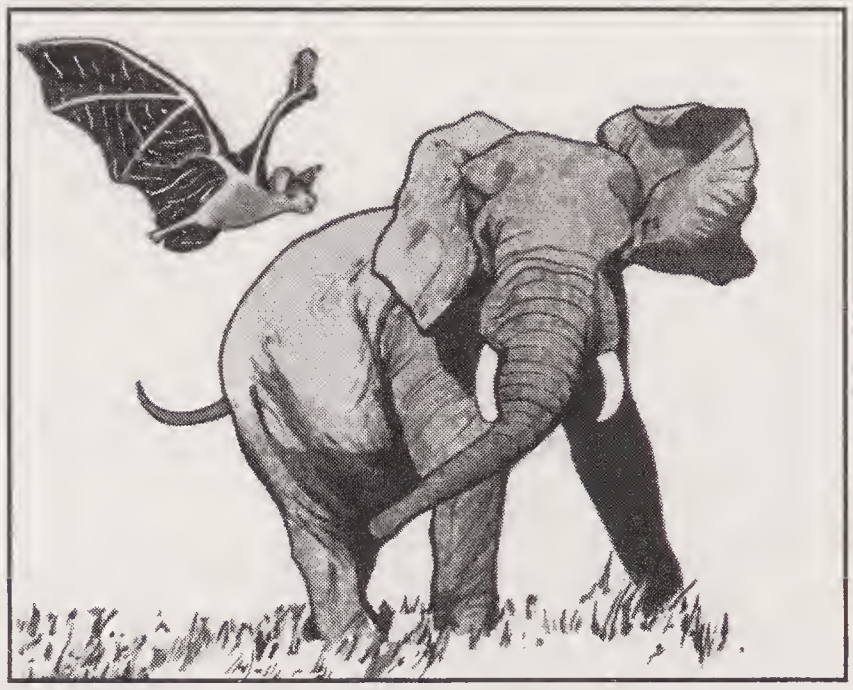
Reptiles



Dinosaurs



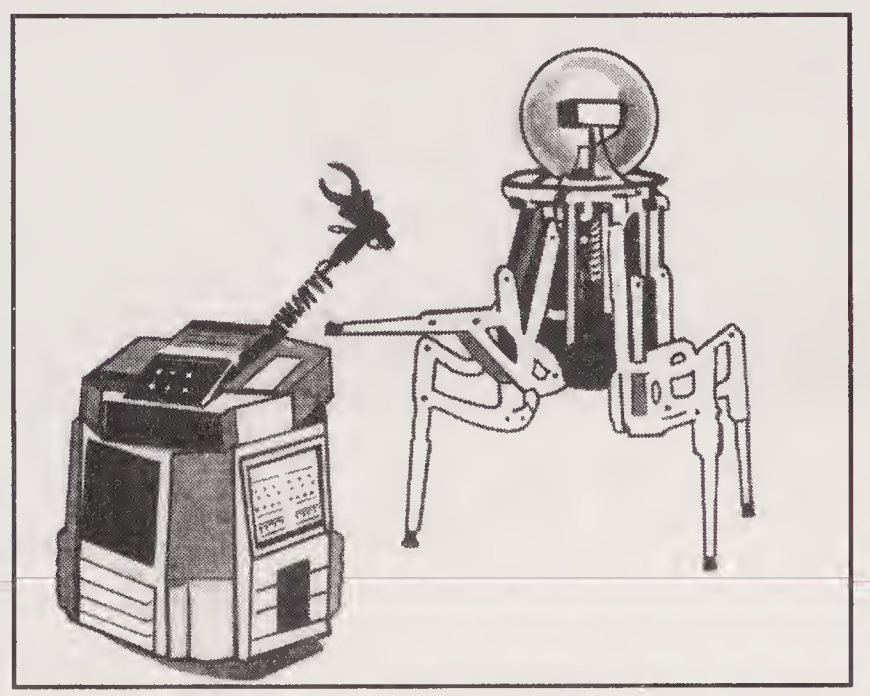
Avians



Mammals

Carniferns

???



allows you to eradicate all members of a particular species in a single act. To do so, hold down the Control key (Option on the Mac) and then select a life form as if you were going to place it on the map. As soon as you select that life form, a message will display telling you that all members of that species have been eradicated. If you choose a life form that has not yet evolved, nothing will happen.

Extincting All Life (Mac only)

If you thought eliminating a species was awesome, you've only scratched the surface. There is a very secret method for getting rid of all life on your planet. Slowly type the letters ERAD on your keyboard, and all life will disappear! And that includes all plant life as well.

Terraform Tools

In addition to life forms and cities, the Place Life tool lets you put special advanced terraforming machines down on a planet. These were created to help you terraform Mars and Venus. Another term meaning basically the same thing as terraforming is ecopoiesis. This term is credited by James Lovelock to Robert Haynes, a geneticist from Toronto. It means, "the making of a home." Whatever term you prefer, these various gas and biome generators, along with the ice meteors, are needed when working with the inhospitable environments of the other planets. Their effects on Earth are less likely to be beneficial, however.

If you want to get rid of one of these terraforming tools, drop a meteor on it, or try a volcano. If you're not looking for such a big disaster, try setting fire to it.

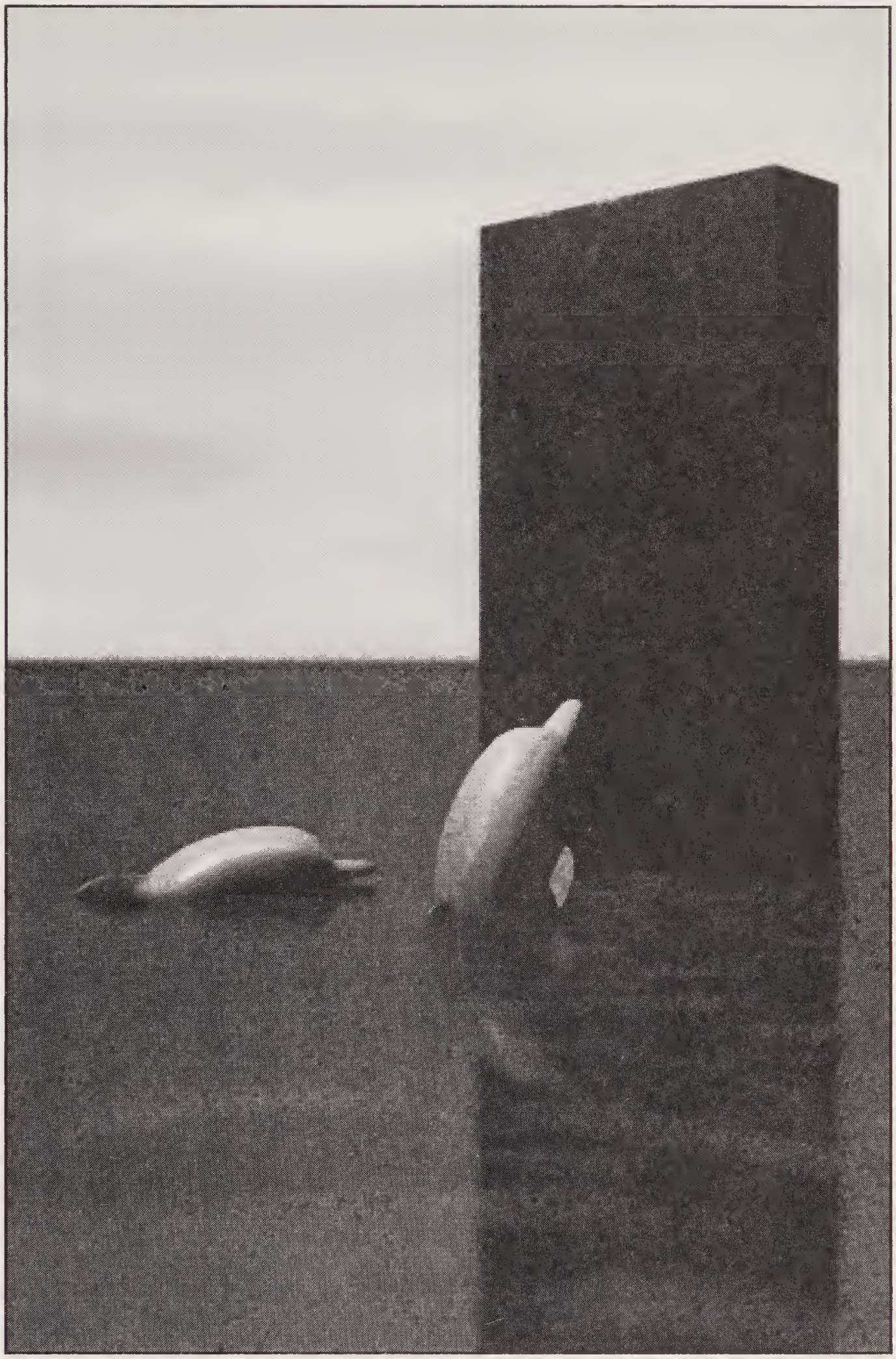
The Biome Factory—The Biome Factory is a remarkable device that can create appropriate biomes for the local environment. It can even change the kind of biome it is creating to compensate for changes in climate and resulting changes in local conditions. This nifty gadget will help you green the dead worlds of Mars and Venus much faster and more efficiently than you could by placing biomes by hand. It costs 500 EU.

The Oxygenator—If your planet needs free oxygen and has too much carbon dioxide, this is the machine for you! Buy one for 500 EU and use it on Venus to cool things down a bit.

The N_2 Generator—Nitrogen is a necessary, if inert, component of our atmosphere, comprising more than 70% of the air we breathe. Among other things, nitrogen helps keep things from burning up. If oxygen levels were to rise above 25%, even wet plants would burn up! Nitrogen also acts to increase atmospheric pressure, which helps the atmosphere retain more heat. Like the others, the N_2 Generator is 500 EU.

The Vaporator—If things get a little too dry, try using one of these oversized vaporizers. It will put more humidity into the air, increasing rainfall and generally wetting things down. Cost is 500 EU.

The CO_2 Generator—Carbon dioxide is an important gas. Not only do plants need it to breathe, but it is an effective greenhouse gas, meaning that it helps a planet retain heat. If a planet is too cold, CO_2 might help warm it. It costs 500 EU.



Will these cetaceans achieve sentience with the monolith?

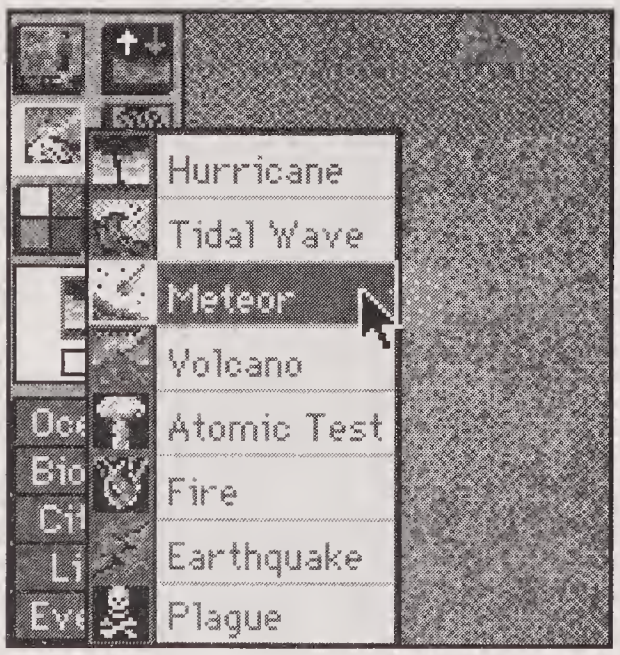
The Monolith—The Monolith, on loan from Arthur C. Clarke, will spark a leap of intelligence in life forms that encounter it. How this works is a mystery, but it has something to do with spontaneous mutation. There is a one in

three chance that the life form you use the Monolith on will mutate upward and reach the next stage of evolution or technology. For instance, using it on a mammal will cause it to reach Stone Age civilization one time out of three. Use it on a Stone Age city and they might evolve instantly to Industrial Age. Use it on Industrial Age or above, and they may take off in the Exodus. Therefore, you can, conceivably, cause a lowly animal to become an advanced star traveller in a matter of years.

The Monolith will not work at all on a species that cannot mutate further. Also, it can be a mixed blessing. Basically, I think the Monolith is a good toy, and a useful tool for exploring some improbable (not to say impossible) scenarios. However, it is such a major level of tampering that its use generally sets up situations that are too artificial—for instance an industrial civilization that occurs before fossil fuels can develop. The Monolith costs 2500 EU.

The Ice Meteor—If a planet needs water, an Ice Meteor is the perfect solution. For only 500 EU, it can help a dry planet find the liquid of life. (On PC compatibles it costs 1000 EU. Sorry.). Don't drop too many, though, or you might flood your planet. Drop one or two and see what happens before you drop another.

The Event Trigger



If you've got a flair for the dramatic, the Event Trigger may be one of your favorite tools in the SimEarth toolbox. For only 50 EU a pop you, too, can cast destruction and the awesome forces of change upon your planet. Choose from a small, but deadly assortment of (mostly natural) disasters including Hurricane, Tidal Wave, Meteor, Volcano, Atomic Test, Fire, Earthquake, and Plague. Accept no substitutes. This is the real thing.

Events in SimEarth are all big events. Small earthquakes, tiny meteors, and miniscule forest fires are simply beneath the notice of this simulation. When a fire burns in SimEarth, it's big enough to have some noticeable effect on the planet's atmosphere. If a volcano erupts, it's going to create a lot of new land or raise huge mountains. It's also going to have a noticeable effect on the atmosphere. And so it goes.

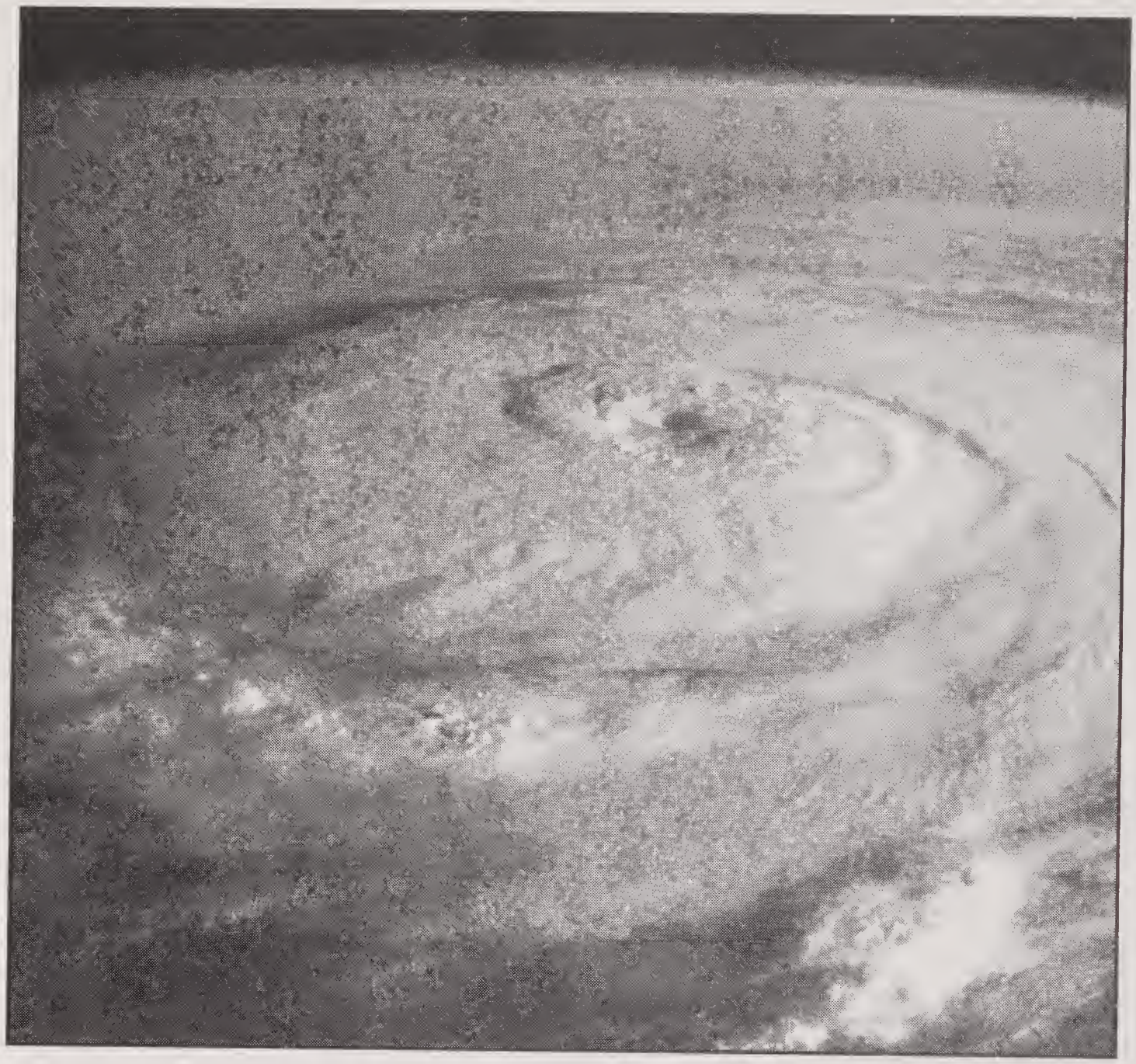
In addition to their destructive potential, events in SimEarth can be tools to affect regional change on your

planet. Many of the tools you have are global tools, especially those in the various Model windows. However, the events in the Event Trigger may have local applications as noted below.

There are three events that occur under certain circumstances, but are not items on the Event Trigger palette: War, Pollution, and Exodus.

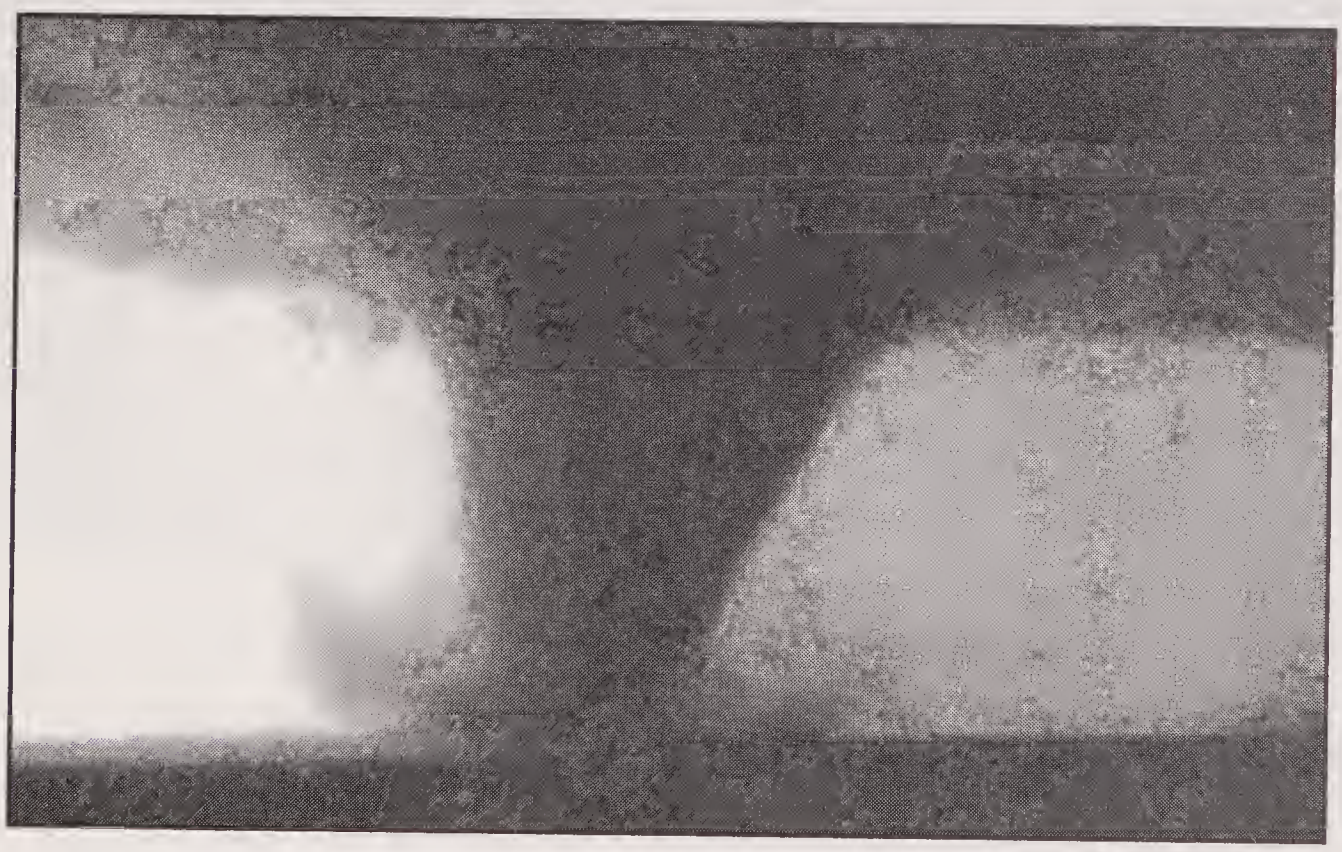
Hurricane

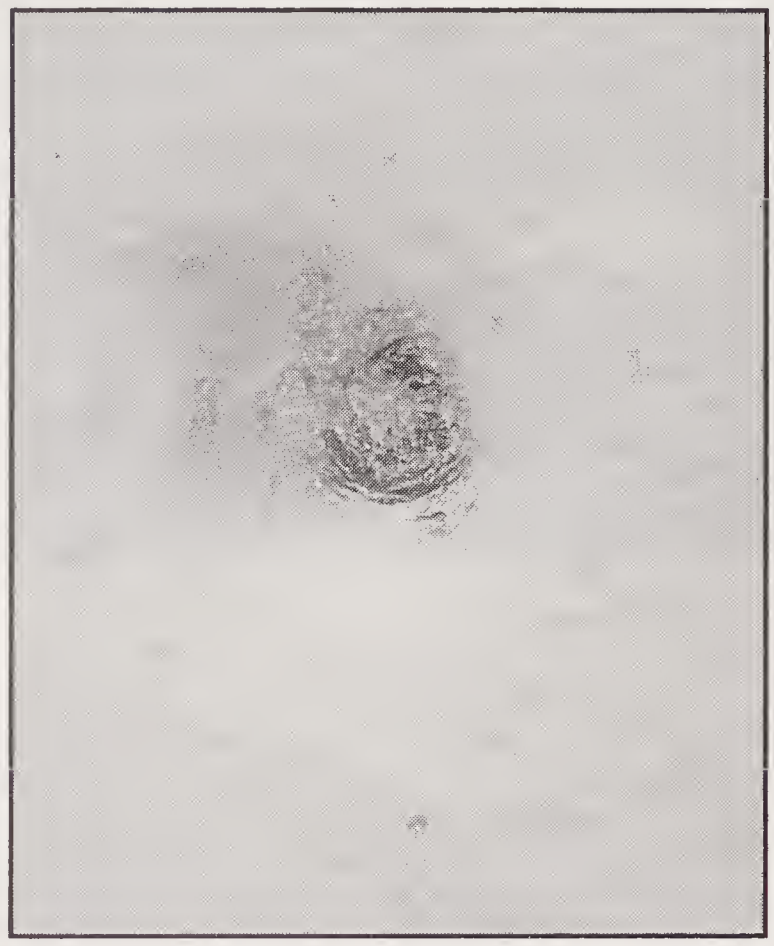
Hurricanes occur naturally, especially in warmer seas. They can cause destruction of coastal areas and increase rainfall where they occur.



1985's Hurricane Elena.

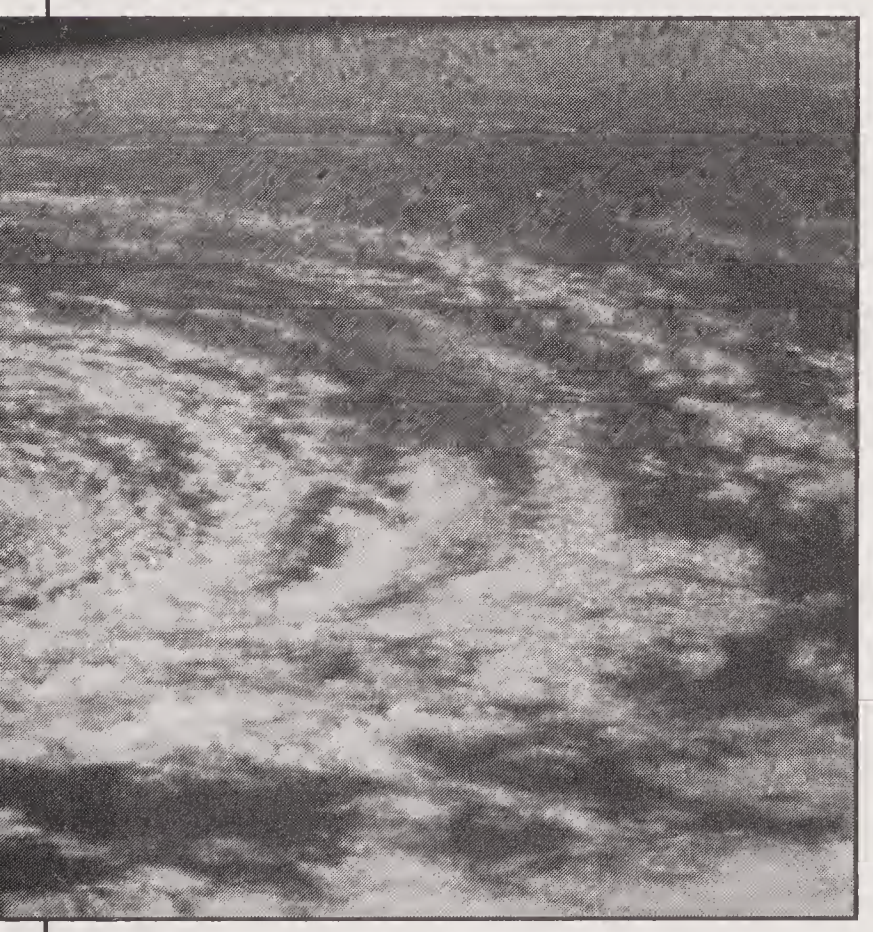
The Awesome Winds





1984: Cyclone Kamysi over the Indian Ocean had winds over 200 km/hr rotating clockwise. Above is a direct look down into the eye of Kamysi.

1985 storm over the Atlantic (below).



Tropical Gyre off the Australian coast in 1985.

A hurricane, while destructive, may also be useful. Set one off in a drought area, and you'll have an instant rainfall fix. Of course, in the real world, the violent winds and rains of a hurricane in a drought-stricken area would probably cause all kinds of erosion and property damage, but in SimEarth it will mostly increase rainfall with some coastal destruction.

Causes: Warm Oceans; Event Trigger.

Effects: High winds, rain, lightning. Local destruction along coastlines and on islands in a hurricane's path.

Local Uses: Increase rainfall. Destroy coastal development.

Counter-Measures: Cool off oceans.

Tidal Wave

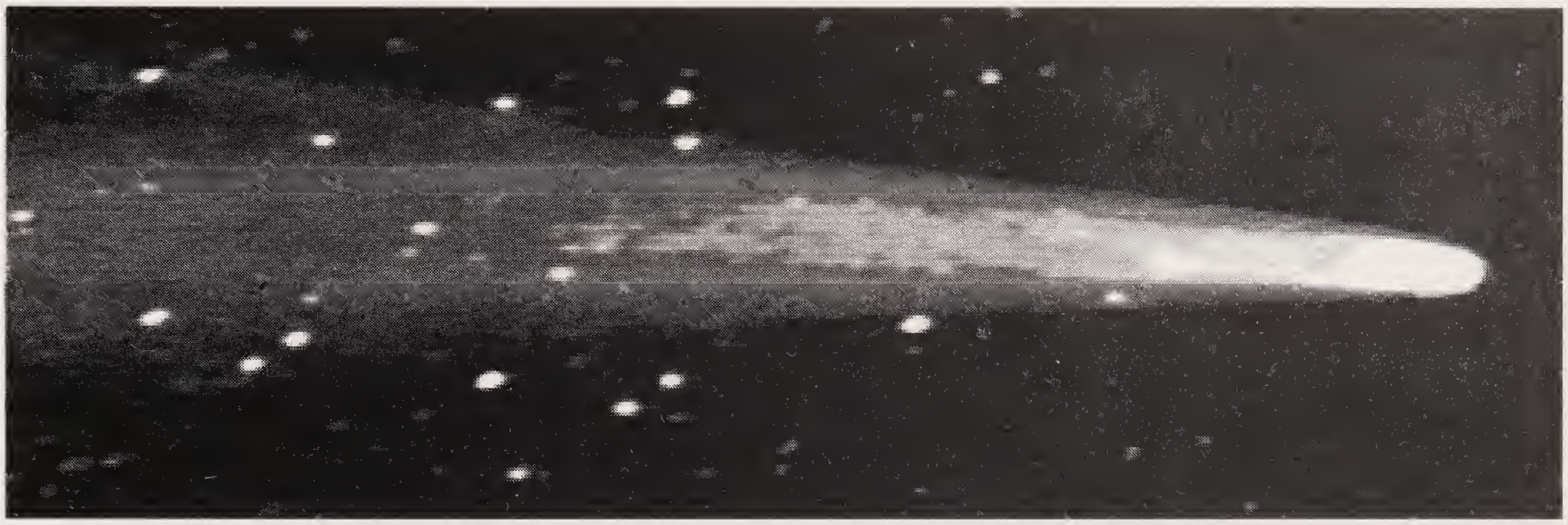
Tidal Waves are huge, destructive waves that usually begin in the deep ocean and travel to shallower water. When they reach land, they may crash over the coastal areas and cause destruction there. Other than to destroy cities on the coasts, tidal waves have no great usefulness.

Causes: Earthquakes, Hurricanes and other high winds, Volcanoes, and Meteors; Event Trigger.

Effects: Huge wave travelling from deep water to shallow; coastal destruction.

Local Uses: Destroying development on coastlines and on small islands.

Counter-Measures: Reduce events that cause them if you can. Don't build cities on low-lying coasts.



Meteor

Meteors have hit the planet consistently throughout its history, and even now, small rocks come into contact with our planet on a regular basis. Most of them burn up in the atmosphere and become shooting stars. A few actually hit, but none in recent times has been of the truly gargantuan size that scientists believe have hit many times in the history of Earth. It is probable that huge planetesimals have impacted the Earth ten or more times, each time wiping out between 50 and 90 percent of the life on the planet. One of the current prevailing theories to explain the extinction of the dinosaurs is that a huge space rock or comet hit the Earth and caused such climate changes that the reptilian masters of the planet were destroyed.

The meteors in SimEarth are big ones. These hunks of space rock can create instant lakes, fill the atmosphere with water vapors or dust (depending on where they land), flatten mountains, and instantly destroy cities that are unlucky enough to find themselves in the impact zone. Meteors that land in the ocean cause tidal waves that radiate out in all directions. They also can have an effect on magma flow causing magma to change directions at the location of the meteor impact.

When a meteor hits land, it sends a cloud of dust into the atmosphere. This dust can block sunlight and, if there is enough of it, can trigger extinctions and planetary cooling.

When a meteor hits water, it sends water vapor into the air which can increase rainfall. Water vapor is also a greenhouse gas, so the effect should be to warm the planet somewhat as well.

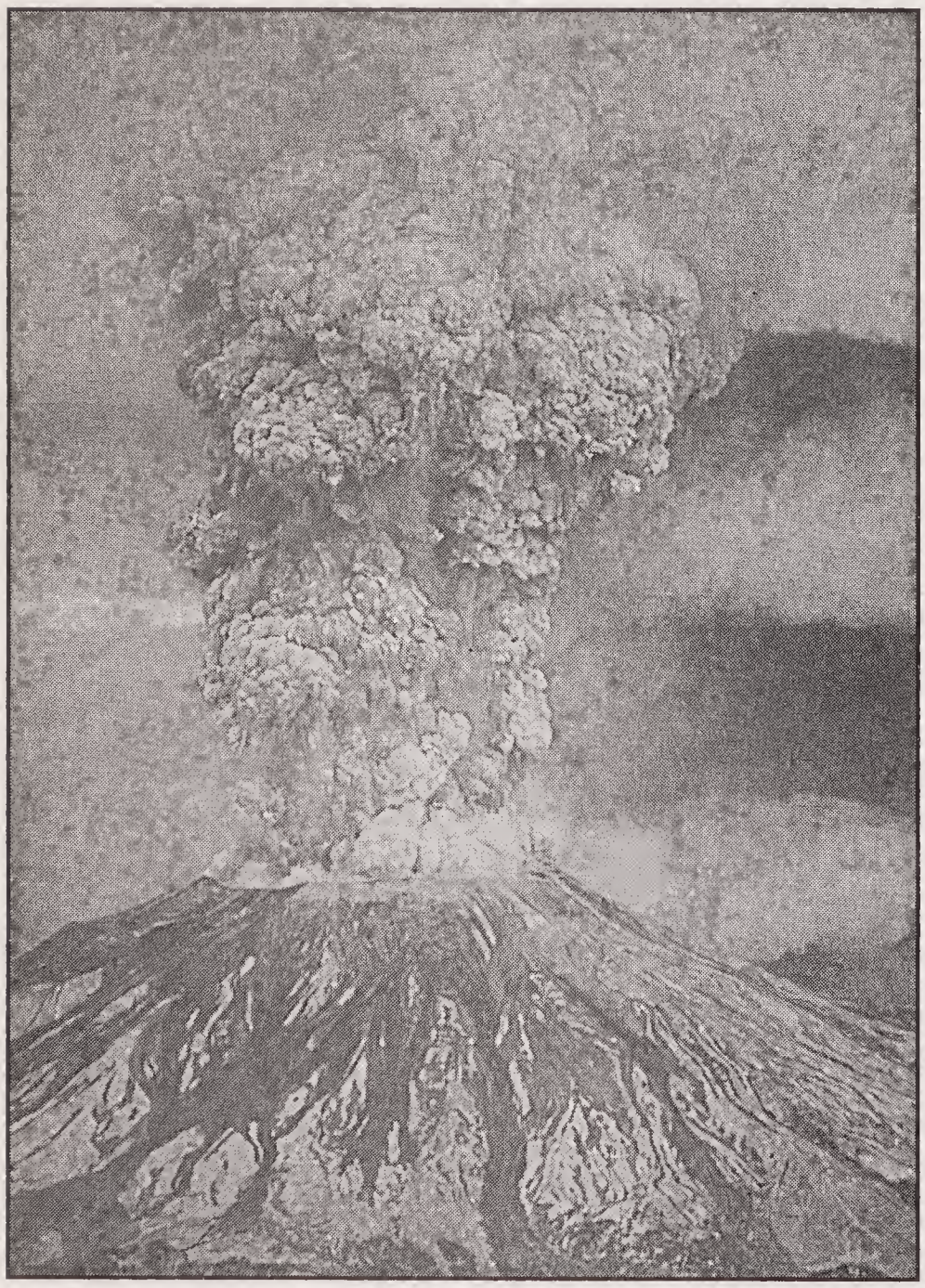
Causes: Pure chance; Event Trigger

Effects: Flatten mountains, create lakes, spew dust or water vapor into the air, cause tidal waves, change direction of magma flow.

Local Uses: Destroy unwanted cities (or anything else), create recreational lakes.

Counter-Measures: None.

Volcano



Mount St. Helens blowing her top.

Volcanoes are one of the main ways we know it's hot down there beneath the surface of the Earth. The pressure of the molten magma beneath the cooler crust of the planet pushes upward and sometimes finds a weak spot where it is able to flow or gush out onto the surface.

Active volcanoes are constantly creating new land as their lava flows out. Islands like those in the Hawaiian chain are formed as the tectonic plate flows over a "hot spot" in the floor of the ocean. The Hawaiian hot spot has formed all the islands in the Hawaiian chain, and is even now forming another one called Loihi east of the Big Island (Hawaii) where the Kilauea Volcano is still erupting—still forming new land.

In SimEarth, volcanoes make Mount St. Helens look like a firecracker, and even dwarf such historical cataclysms as Krakatoa and the 1815 eruption of Mount Tambora in Indonesia (which was reputed to be about 100 times the size of the Mount St. Helens eruption). SimVolcanoes also happen very

quickly. While earthly volcanoes can erupt violently and build up huge mountains in a matter of days, in SimEarth, volcanoes appear to pop out onto the surface of the planet instantaneously.

Remember, the time frame you're viewing is often very fast, though. Each tick of the clock represents a minimum of a tenth of a year (a little more than a month) in the Technological time scale, to as much as 250 million years in the Geological time scale. Under those circumstances almost any event will seem quick. In fact, the time scale can sometimes be a little unrealistic. For instance, a hurricane might last hundreds of thousands of years in the Cambrian period where each tick of the clock represents 250 thousand years.

Volcanoes hurl lots of molten rock (lava) out of the earth. In addition, they release gases, dust and aerosols (tiny particles of matter that float in the air). The CO_2 can cause some increase in the greenhouse effect, perhaps helping heat the planet, while the dust works in the opposite way by blocking sunlight. Even though volcanoes are one of the best ways to create new land masses, creating too many of them could have noticeable (and potentially disastrous) effects on planetary life.

Causes: Random events (influenced by Core Heat, Core Size, and Volcanic Activity on Geosphere Model Control Panel); Event Trigger.

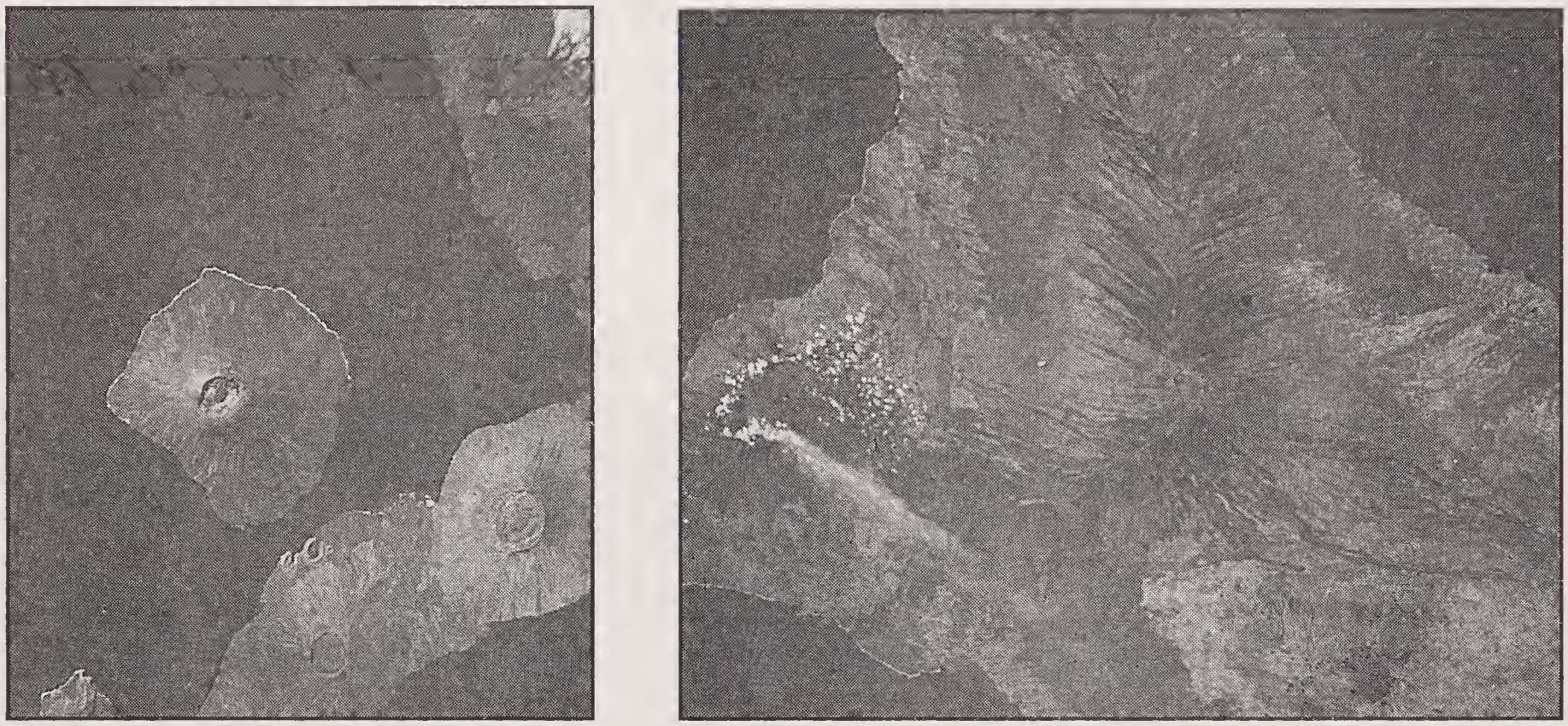
Effects: New land built in oceans, higher mountains on land; dust and CO_2 in the air.

Local Uses: Create new land or raise the altitude of existing land.

Counter-Measures: Reduce Volcanic Activity, Increase Core Size, Reduce Core Heat in the Geologic Model Control Panel.

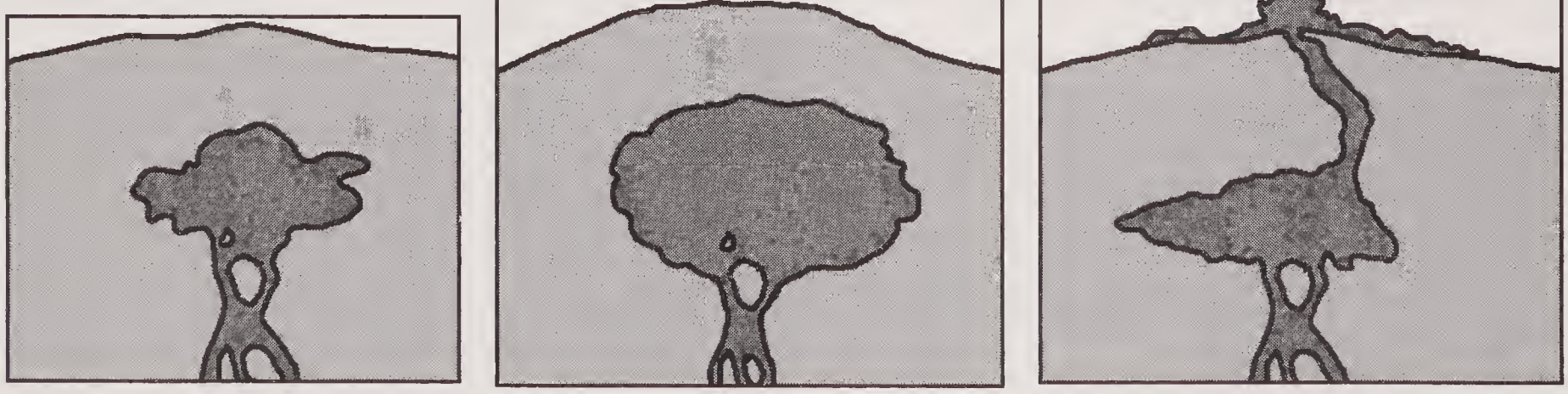
VOLCANOES

Volcanoes form in two basic areas. The first is near the rift zones of the tectonic plates where new land is forming and folding. These rifts are like cracks in an egg, and they expose the hot, molten interior of the Earth to the surface. At these points, volcanoes are likely to form. Volcanoes in the Pacific Rim, otherwise known as the Ring of Fire, are examples of this kind of event.



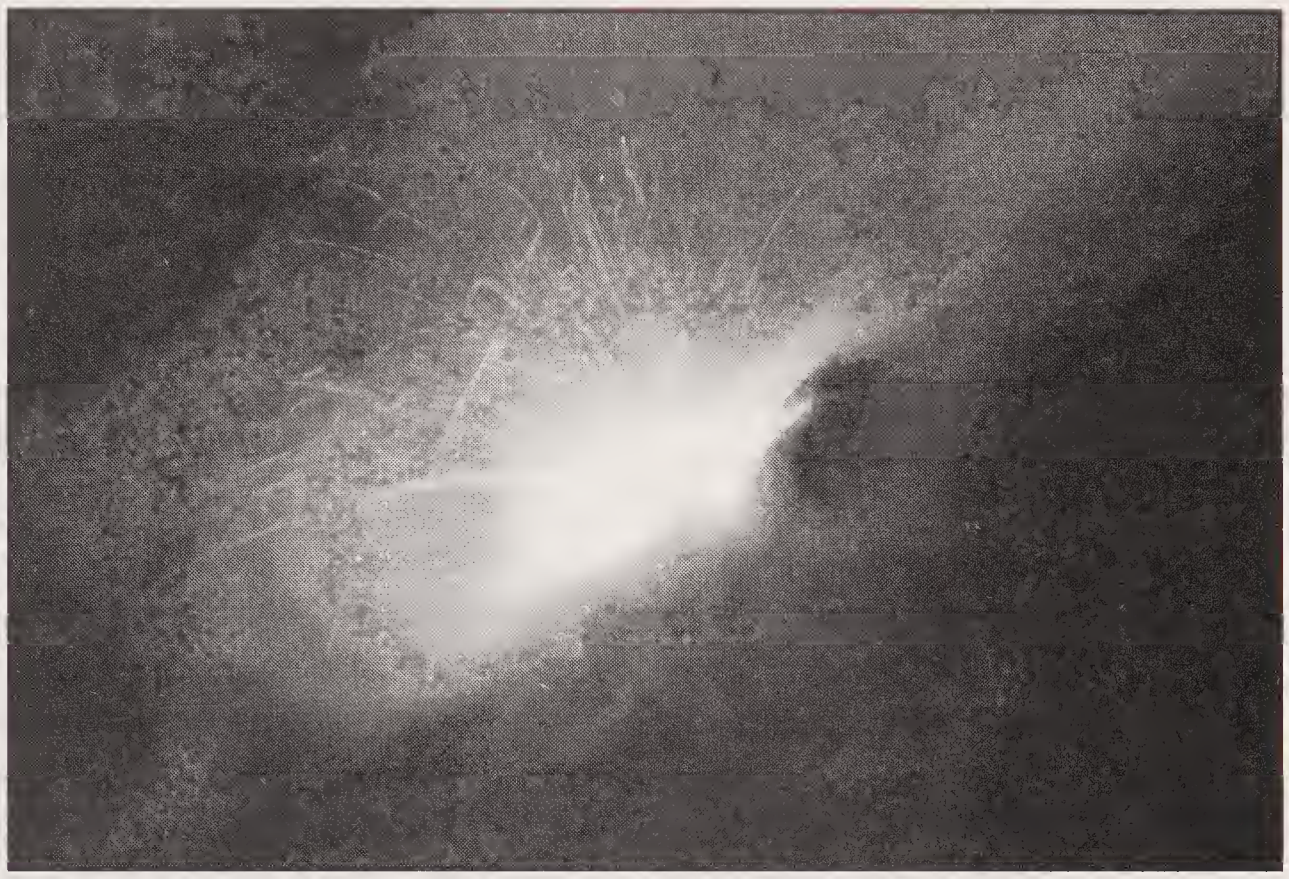
Some famous hot spots—Galapagos and Hawaii

On the other hand, some volcanoes form in places far from the tectonic plate boundaries. These are so-called hot spots—thin areas in the Earth's crust where the underground pressures build up and burst forth in volcanic activity. An example of a hot spot is the area of the Hawaiian Islands. Far from any plate boundaries, the Hawaiian chain has all been built by volcanic activity. Over the three thousand miles of the chain, one can witness the results of the tectonic movement. Each island in



The magma reservoir swells, the ground tilts, and then gives way as the volcano erupts.

the chain, beginning with the oldest, the Kure atoll, and currently ending with the Big Island of Hawaii, has been formed by the same hot spot. The only explanation for that fact is that the actual sea floor has been moving and as it moves, it creates new islands. For instance, both Hawaii and Maui each were formed by two different volcanoes which flowed together to form one island. Even though the island of Hawaii is still forming as Kilauea continues to erupt, a new island named Loihi is already starting to form under water east of Hawaii, and eventually it will form the newest island in the chain.



Scenes from the Big Island.

Photos by G. Brad Lewis

Atomic Test

The Atomic Test is the only phenomenon in the Event Trigger palette that is not a natural event. Even though nuclear reactors actually occurred in nature (see sidebar), there is no evidence of any atomic bomb explosions until Man came to set them off.

You'll find that atomic bombs have little noticeable effect on the early planet. Over the course of millions of years, even the radioactivity they leave behind is expended or dissipated. However, they can have more serious consequences to life in the Civilization time scale. The most benign effect of a nuclear blast is its long-lasting radioactivity which can make an area unlivable for many thousands of years. On the other hand, wholesale use of nuclear bombs, as in a nuclear war, can cause a nuclear winter by obscuring the sun. In a nuclear winter, it is possible that most life on Earth would die. The only really certain survivors would be the specialized tubeworms and other creatures that live down in the deep oceans and don't depend on sunlight at all for their survival, drawing sustenance directly from the minerals of the Earth at special undersea vents.

Causes: Nuclear War; Event Trigger.

Effects: Long-term radiation, atmospheric dust contamination (nuclear winter).

Local Uses: Destruction pure and simple (but not really as effective as a meteor).

Counter-Measures: Reduce Nuclear energy usage on Civilization Model Control Panel.

Fire

Fire is one of the most common of the events available through the Event Trigger palette of options. Fires occur with regularity on our planet. Many of them are directly the result of Man's intervention, but fires also occur due to natural

The First Nuclear Reactor?

Man has taken thousands of years to discover the secret of nuclear energy, but most people would be surprised to learn that ours are not the first nuclear reactors. Even before the ancient Egyptians, the Greek philosopher/scientists, or the ancient Incas, all known for their advanced levels of inquiry and understanding of the world around them, nuclear energy had been harnessed. Its use was certainly without much purpose, but the first known nuclear reactor actually developed about 1.8 billion years ago, when Man was not even a remote possibility and not even the dinosaurs had begun their reign. And yet, in a place called Oklo in Gabon, Africa, scientists have discovered the remains of what must have been a self-sustaining nuclear reactor that probably created power at the kilowatt level for millions of years. This event was due to the unusual talent of a specific algae that had the capacity to absorb uranium dissolved in water. In this one place, a relatively large amount of uranium flowed in the stream leading to Oklo. The organisms left a deposit of uranium oxide, and, cooled by the constant stream of water, the "reactor" reached critical mass and began the characteristic chain reactions that output energy much the same way that modern nuclear reactors do. The presence of the water kept the chain reaction from being explosive, and so the reactor continued until the level of ^{235}U fell below the critical level. In the scheme of things, this means little, other than to confirm the Shakespearean quote:

> *There are more things in heaven and earth, Horatio*
> *Than are dreamt of in your philosophy.*

Oxygen

In *The Ages of Gaia*, James Lovelock talks about the effects of oxygen in the atmosphere. Among other ideas, he shows the remarkable balance that our planet has struck between two unacceptable levels of oxygen. "Oxygen has been constant at 21 percent by volume in the Phanerozoic*. The evidence of this constant high concentration is the presence in the sediments of layers containing charcoal. These can be found as far back as 200 million years. The presence of charcoal implies fires, probably forest fires. This sets sharp limits on the atmospheric oxygen abundance. My colleague, Andrew Watson, showed that fires cannot be started, even in dry twigs, when oxygen is below 15 percent; above 25 percent oxygen, fires are so fierce that even the damp wood of a tropical rain forest would burn in an awesome conflagration. Below 15 percent there could be no charcoal; above 25 percent no forests."

**Phanerozoic—the period during which plants and animals have existed.*

causes like lightning strikes, spontaneous combustion, or volcanic eruptions. In SimEarth, fires are large enough to cause noticeable effects on the oxygen levels of the atmosphere. Fires will break out spontaneously if oxygen levels rise beyond about 23-24 percent. Above 25 percent, almost every organic object on the planet would spontaneously combust, even wet materials.

Causes: Natural causes, high oxygen levels; Event Trigger.

Effects: Consumes oxygen; has a small effect on local biomes.

Local Uses: Destroy local vegetation, cities, nanotech generators.

Counter-Measures: Keep oxygen levels normal.

Earthquake

In nature, earthquakes most often occur when the tectonic plates crash into each other or scrape past each other. We feel these ground shifts as unbelievably powerful events in our lives. They can shake our houses apart, destroy cities, even cause large sections of land to disappear as parts of continents break apart. And yet, these are small upheavals in the scope of the Earth itself. They are settlings of small tensions between moving land masses. An earthquake that could destroy a huge city might be no more than a temporary relieving of tension in a small area of a huge fault.

In SimEarth, the relationship between magma flow and earthquakes is reversed from reality. Whereas, in the real world, magma flow causes the continental drift that eventually causes two tectonic plates to collide or in some way intersect, in SimEarth, earthquakes can affect the magma flow directly. Although this is not a realistic model, it does give you a way to play a direct part in such events as mountain building and continental drift.

The best way to see what happens when you set off an earthquake in the Geologic time period is to switch the

Map window to the Continental Drift view. This shows the direction of magma flow, and therefore the direction the continents are traveling. Select Earthquake from the Event Trigger and a supplementary palette will appear showing the choices for earthquake direction. Choose the appropriate direction you want the earthquake's force to move, then click in the Edit window to cause the quake. The direction of the earthquake also changes the direction of magma flow for that part of the planet, so you'll see the magma flow lines change to the direction you chose.

Use earthquakes to create mountain ranges by sending two plates directly at each other. Create a supercontinent by hurling all your continents to one place. Or rip a continent apart by causing earthquakes that split it. Earthquakes can be fun ways to reshape a planet's land surfaces.

Earthquakes don't have very noticeable effects on cities, however.

Causes: Interacting tectonic plates; Event Trigger

Effects: Change magma flow, tidal waves, shake things up.

Local Uses: Change the direction of continental drift.

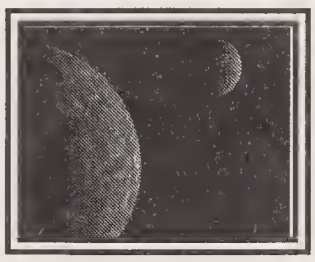
Counter-Measures: None.

Other Events

There are some events you can't control from the Event Trigger, but we've included them here to complete the event list.

Plague

Disease has always been a problem for civilization. Some diseases can decimate large segments of a population. In fairly recent history there was the Black Plague of Europe. However, millions die today from diseases originated in contaminated water and spread through overpopulated regions. And even though modern medicine has virtually eliminated some formerly deadly diseases, new plagues can appear at any time. Today, we face the threat of AIDS, for instance.



EARTHQUAKES

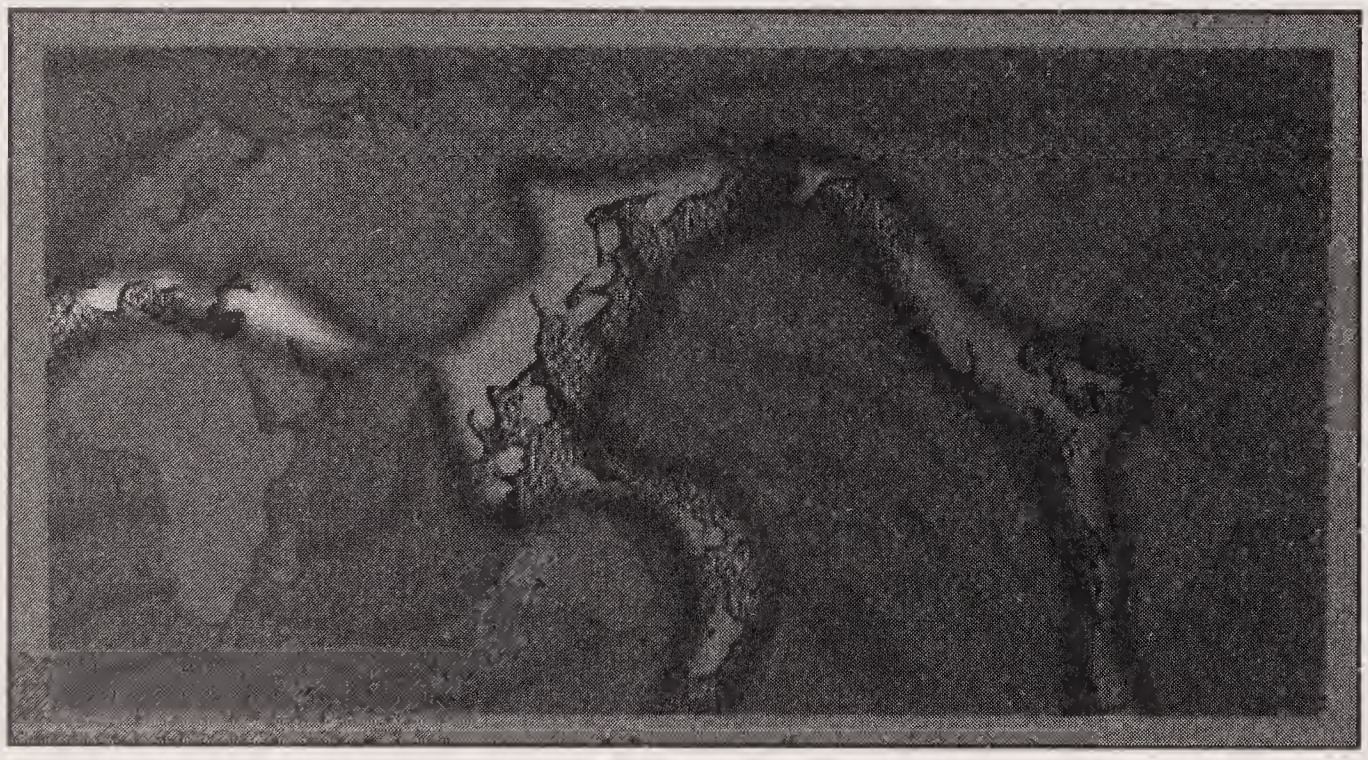
Earthquakes have been around much longer than Man, and the explanations for them certainly exercised the imagination of early peoples. As Jonathan Weiner points out in *Planet Earth*, early civilizations saw earthquakes in many ways. One tribe in Africa saw the jungle as the hair of a giant god and earthquakes happened when he shook his head to get rid of lice. Other explanations involved the thrashings of a hooked fish or the tantrums of a spurned goddess (Pele in Hawaii). The ancient Norsemen saw the shaking as Loki's writhing when a drop of poison fell upon him as part of his punishment from Odin for his misdeeds.

As late as the 16th century, people were suggesting such remedies as placing statues of Mercury and Saturn at the corners of buildings as a sort of mystical earthquake insurance. An early naturalistic explanation for earthquakes was that they were caused by air that rushed from within caverns deep in the Earth.

As colorful as all these mythical explanations were, the truth is both more mundane, and in some ways more awesome. Earthquakes are the result of the movement of the tectonic plates of the Earth. Where two plates slide along each other is called a fault, and it is at the faults that most major earthquakes occur. Some minor earthquakes may occur near volcanoes, which explains why there are earthquakes from time to time in Hawaii, far from the edges of any plate. A sudden increase in earthquake activity in the vicinity of volcanoes is often an indicator that eruptions may not be far off. However, the major faults produce the major quakes.

One of the earliest documented quakes occurred in Lisbon, Portugal in 1755. This tremor was so powerful that buildings were rattled throughout Europe and chandeliers rattled as far away as the United States. Another major quake occurred in New Madrid, Missouri in 1811. Shocks from this earthquake were felt over an area of 2 million square miles.

A large proportion of the major earthquakes of the world occur in the Pacific Rim, known also as the Ring of Fire. Around this rim are many tectonic plate intersections. A good example is the San Andreas fault which is found at the boundary between the Pacific Plate to the west and the North American Plate to the east. The Pacific Plate is moving in a northwestward direction relative to the North American Plate. The San Andreas fault is more than 800 miles long and extends up to ten miles down into the

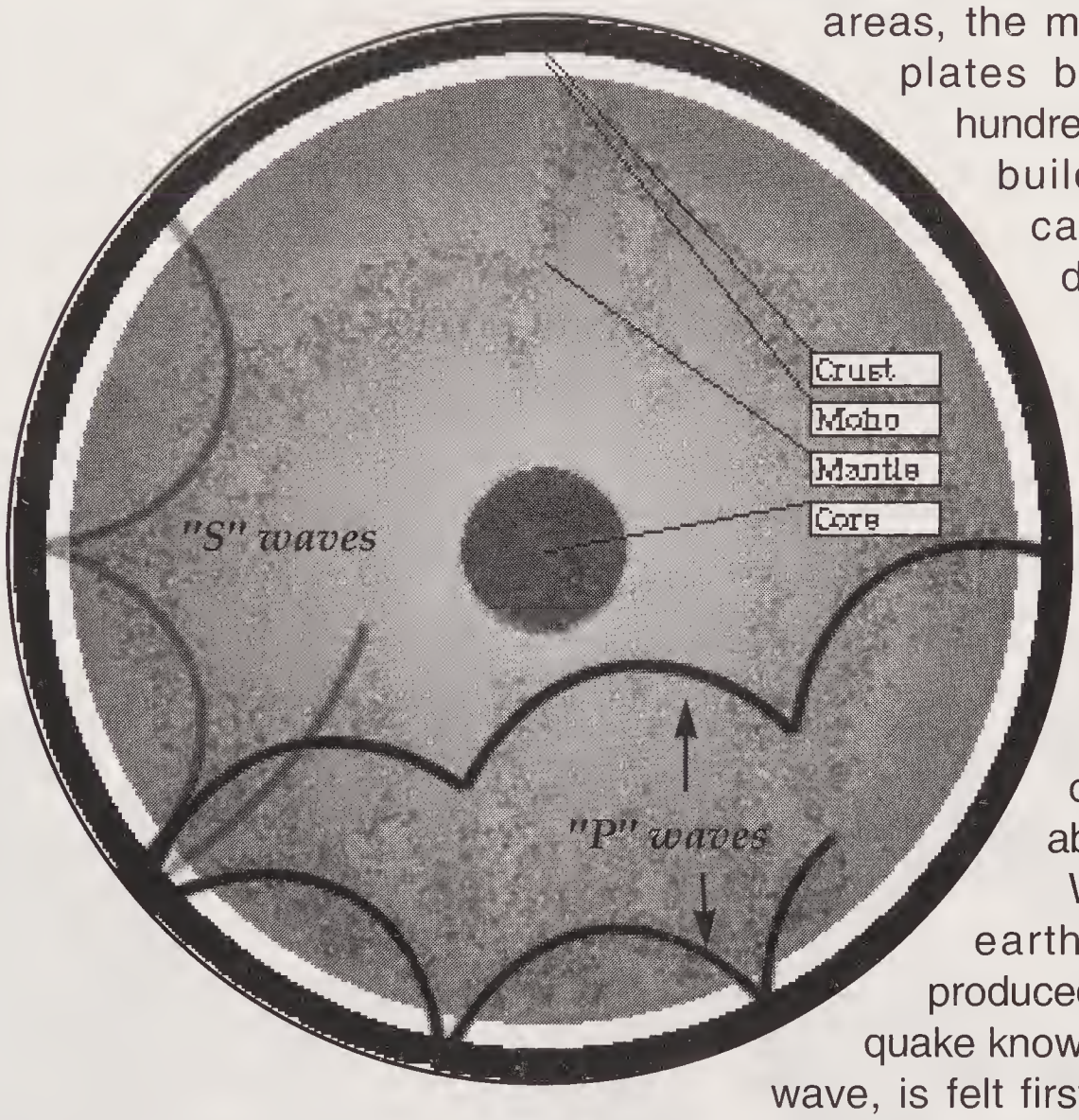


The major earthquake zones of the world.

Earth's crust. The fault itself is composed of an area of crushed and broken rock from a few hundred feet to a mile wide.

The San Andreas fault is famous for its 1906 earthquake that decimated the city of San Francisco. It is also responsible for the recent interruption of the World Series when another major quake hit the city by the bay. However, the San Andreas fault extends many miles north of San Francisco and many miles south. It also connects to many other faults like the Hayward fault, also in the Bay Area, and the Banning and San Jacinto faults in southern California.

As the sections of the plates slide along each other, moving either horizontally or vertically relative to each other, they build up tension in some areas. That tension is often relieved by small movements, which cause minor tremors hardly noticed by people. These areas are known as "creeping sections." However, in other areas, the movement is more "sticky" and the plates become locked for as much as hundreds of years. When enough pressure builds up, a major shift can occur, causing an earthquake with great destructive tendencies. During the 1906 earthquake, one section near Tomales Bay was recorded to have offset by 21 feet as the ground west of the fault moved relatively northward. In fact, over the 15-20 million years that scientists believe the fault to have existed, the cumulative movement is estimated to be at least 350 miles! This is consistent with current estimates of about 2 inches of drift per year.



When the crust shifts causing an earthquake, two kinds of waves are produced, emanating from the location of the quake known as the epicenter. The primary, or P wave, is felt first. This is a compression wave that travels very quickly through the earth and is experienced as an explosive, sharp, blastlike shock. Some seconds later, the transverse or shear waves (S waves) arrive and are experienced as rolling or swaying.

Earthquakes also occur under the sea—sometimes causing tidal waves (tsunamis).

There is no way to prevent earthquakes, but appropriate building codes can avoid damage to life and property. This was demonstrated during the recent quake in San Francisco where buildings have long been designed to withstand earthquakes. Even though a great deal of damage was caused, most experts agree that it could have been much worse, and the loss of life was remarkably low for the size of the quake and its proximity to a major population center.

In SimEarth, plagues usually start in the more underdeveloped cities, but can quickly spread to the more advanced cities. Plagues will cause a serious problem as your population centers begin to occur closer and closer together in the Technology time scale. Increasing the Medical setting on the Civilization Model Control Panel will help keep plagues under control.

Causes: Natural result of crowding in and around cities; Event Trigger.

Effects: Destroys whole cities and can spread to nearby ones.

Local Uses: Not much good unless you want a lot of people to die.

Counter-Measures: Raise Medicine in Civilization Model Control Panel.

War

Intelligent species in SimEarth, like their counterparts on Earth, haven't really learned to get along very well, but you

can help them. They have a tendency to fight among themselves, but if you raise their level of Philosophy (in the Civilization Model Control Panel), they will tend to fight less.

In fact, in SimEarth small wars are not all that devastating to the spread of life and technology. Therefore, in some scenarios, it isn't necessary to try to avoid war altogether to get your species off the planet in Exodus. However, if your personal philosophy is more peaceful, you may want to experiment with promoting a civilization without war.

Fear the goat from the front, the horse from the rear, and the man from all sides.

—Russian proverb

The only kind of war that can seriously threaten your civilization is nuclear war. To avoid nuclear war, simply don't use nuclear fuels. Without nuclear fuels, there is no nuclear war. It may seem that this is a radical solution, but, in SimEarth at least, it is possible to evolve to the highest levels of civilization without the use of nuclear or fossil fuels!

Causes: Low Philosophy, competition for nuclear fuels.

Effects: Lower population (except in the case of nuclear war—see Atomic Test above).

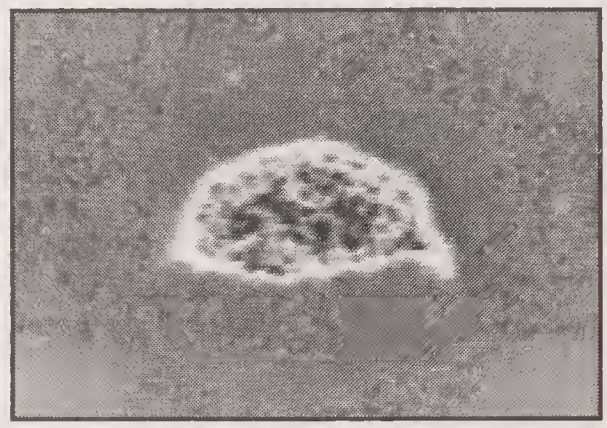
Local Uses: There are no local uses of war since you don't have any local control over it.

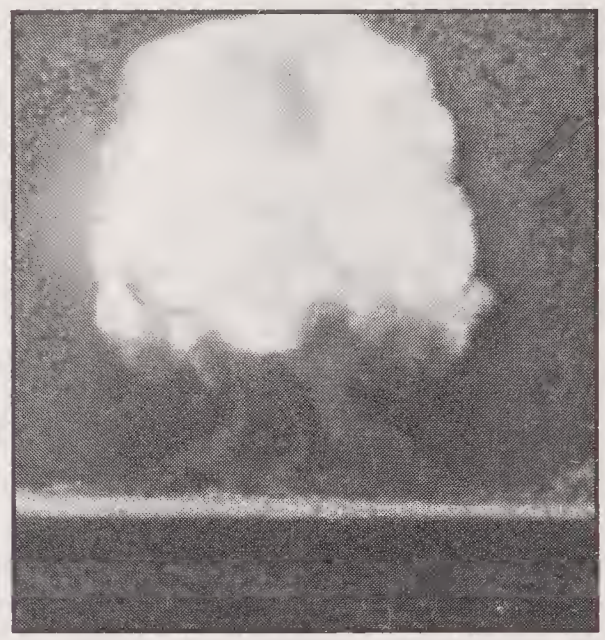
Counter-Measures: Raise Philosophy and don't use nuclear fuel.

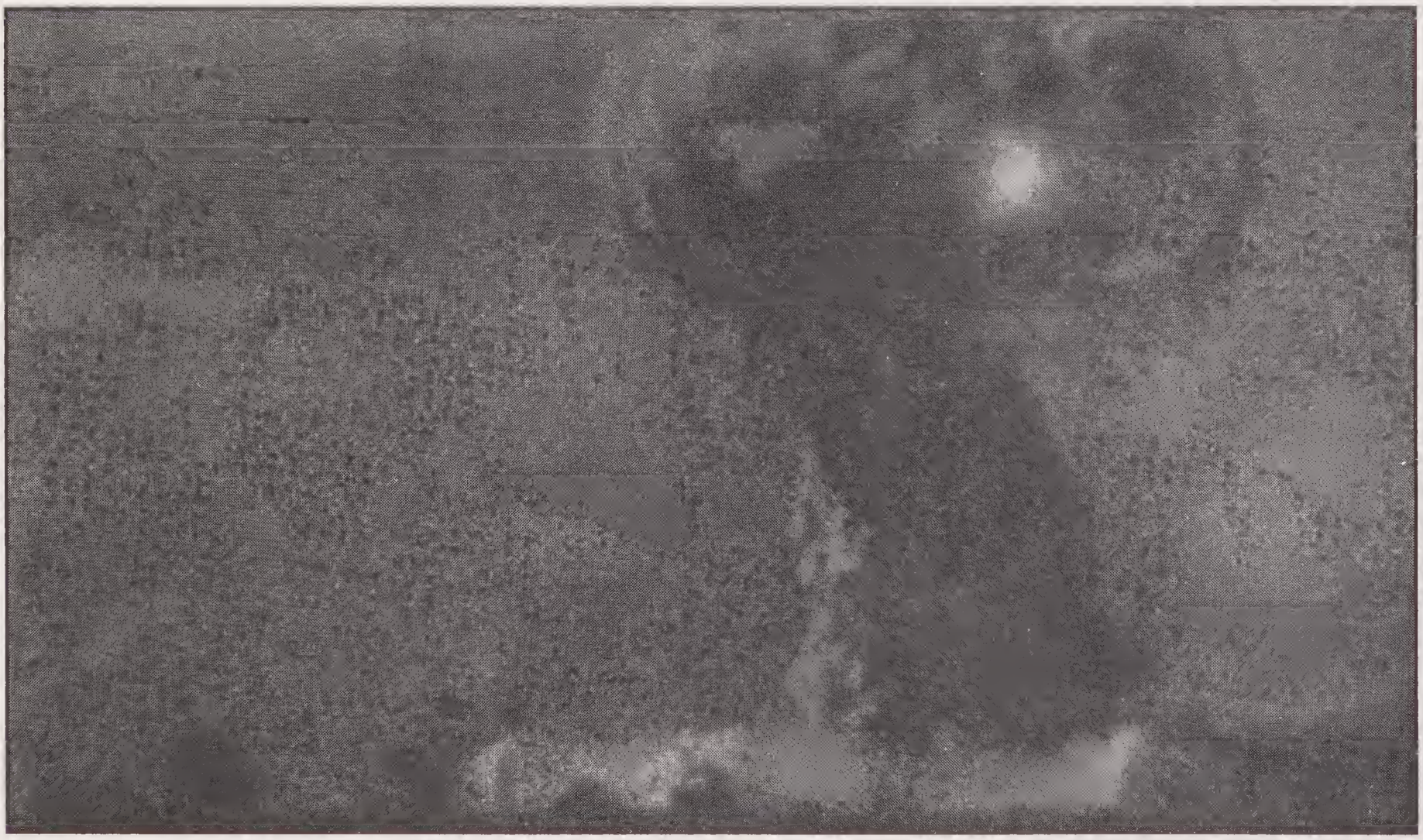
Pollution

One of the byproducts of the Industrial Revolution is increased pollution in the air, the water, and on the land. In SimEarth, pollution acts as a warning that life is being threatened. There will likely be a rise in CO_2 levels, which will trigger global warning. However, there are other effects that aren't so noticeable. Using non-polluting energy sources will vastly reduce pollution problems. Moreover, pollution is at its worst during the Industrial Age. From the Atomic Age on, pollution starts to fall off (there aren't any Chernobyls in

Scenes of War





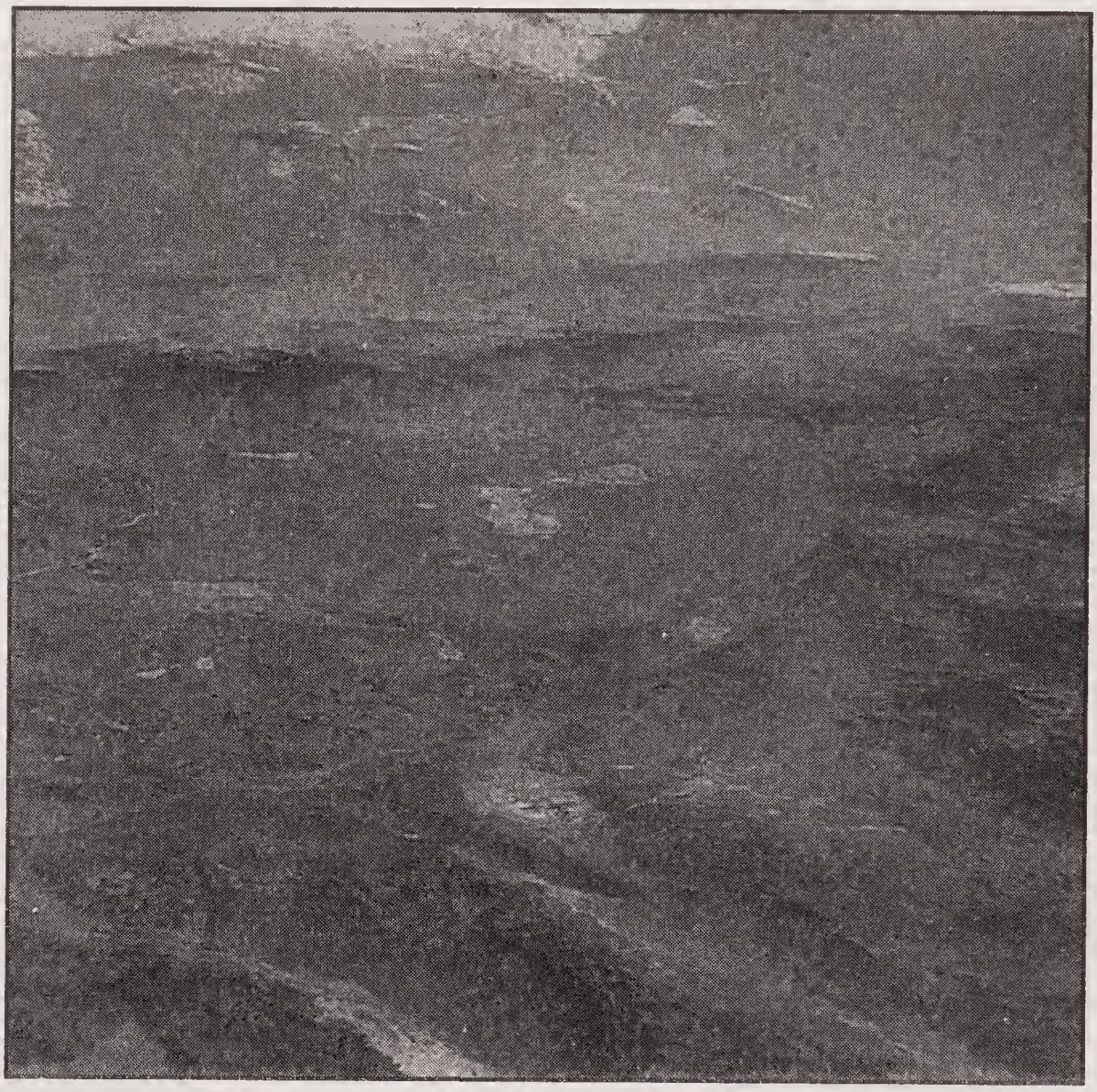


Scenes of Destruction

POLLUTION

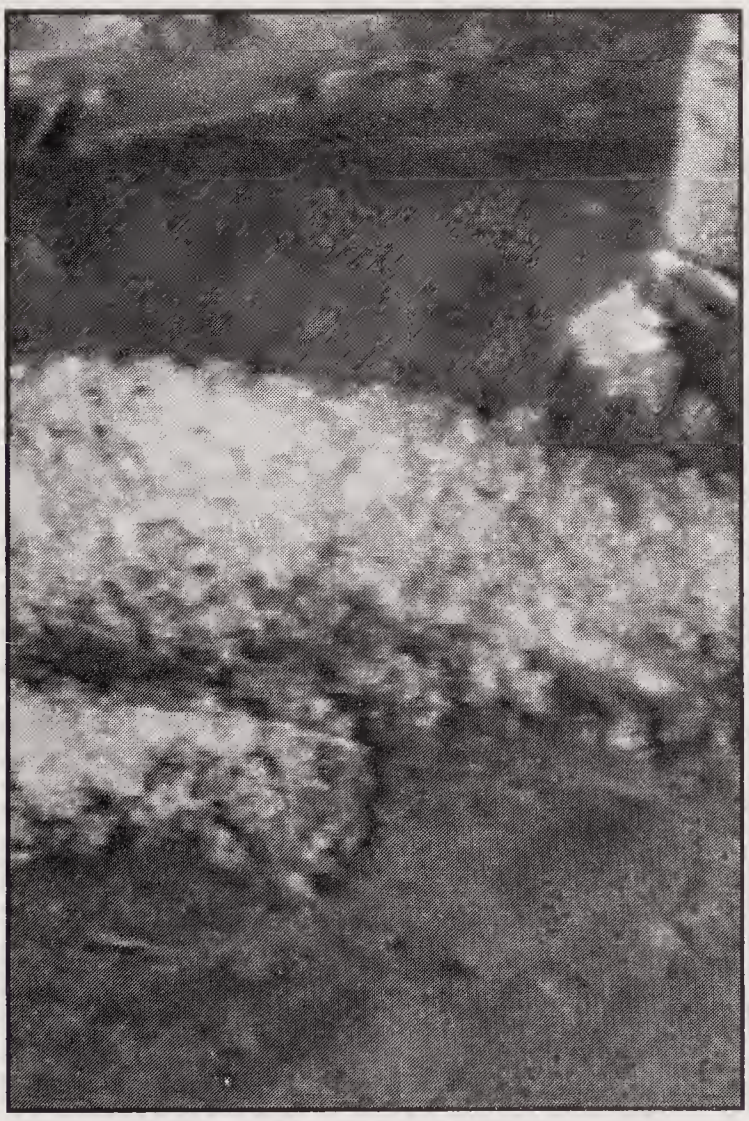
Our world is full of our own trash. It's in the air, on the land, and in the oceans. To the right is an image of smog over the San Gabriel Mountains spilling out from the Los Angeles Basin into the Mojave Desert.

Below are scenes from Baltimore Harbor. Unfortunately, these scenes are typical.



The Exxon Valdez

Scenes from the Exxon Valdez tragedy:
dead otters (below left) and stepping through oil (below right).



the game). There are, however, oil spills, which you will notice from time to time.

By the way, even if you don't use any fossil or nuclear fuels, there will be some pollution in advanced civilizations. However, it should stay fairly manageable.

Causes: Industrial pollution.

Effects: Rise in carbon dioxide.

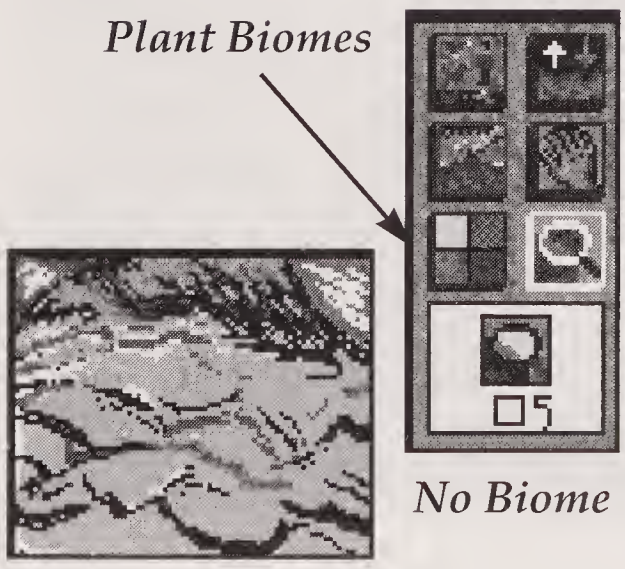
Local Uses: None.

Counter-Measures: Lower use of fossil fuels; get past Industrial Age as fast as possible.

Exodus

When your civilization has reached the Nanotech Age, it is ready to take control of its destiny. It now controls the most awesome powers over matter and energy. If it continues to seek new scientific discoveries, and it is able to produce enough energy output, it will eventually outgrow the planet, take to the stars, and leave behind a pristine world that houses plants and animals in a park-like state. This is called the Exodus. It is when civilization comes of age and joins the interstellar community that may or may not exist out there. At any rate, it will go on a much longer than five year mission of exploration at that time. It will go where no man, or reptile, or jellyfish, or whatever has gone before.

Plant Biomes



Biomes are communities or habitats of specific plants and animals. They are ecological systems like forests or deserts. In SimEarth, there are seven plant biomes as well as a rock, or non-biome. Each biome represents a possible habitat for SimLife, though some life forms can only live in certain biomes, and most life forms have biomes they prefer and others they only tolerate. In the case of aquatic creatures like fish, there is no land biome they can live in. As far as SimEarth is concerned, the ocean is not a specific biome, though of course it is an ecosystem.

Biomes naturally develop at the beginning of the Cambrian Period, and spread across the land surfaces of a planet quite fast. A combination of temperature and rainfall determine what kind of biome will appear in a given spot. Since temperature is often a function of altitude, to a certain extent the altitude helps determine the appropriate biome.

Biome Preferences

	Dry	***Moderate***	***Wet***
	(<30)	(30-90)	(>90)*
Cold (<0º C)	Arctic	Boreal	Boreal
Moderate (0-25º C)	Desert	Grass	Forest
Hot (>25º C)	Desert	Swamp	Jungle

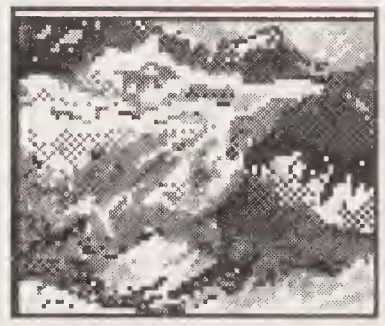
* cm/yr

Although biomes tend to develop naturally, for 50 EU you can place a biome anywhere you want. Its chances of success depend on its being placed in a suitable location, however. A desert isn't likely to last long in a place with a lot of rainfall, and tropical jungles don't thrive at the tops of mountains. If they did, it would probably mean that the temperatures at sea level were extreme. However, if the conditions are marginal, you may be able to place one biome to compete with another. Where there is no biome (plain rock) you may be able to place one, if you choose the right one.

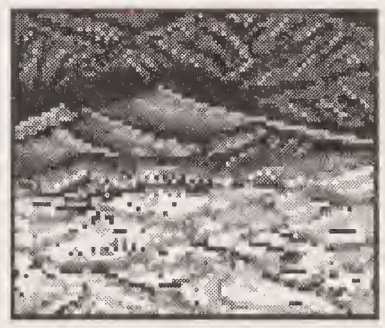
When Gaia regulation is active in the model, biomes tend to spread quickly across the surface of the land from the beginning of the Evolution Time Scale onward. However, in the Hard mode of play, with no Gaia regulation, you may have to help the biomes along more. They don't spread nearly as fast.

The best way to understand what makes a biome successful is to use the Examine tool to examine the conditions that exist at certain places on the map. That way, if you want to know why one part of a continent is grassland and right next to it is a swamp that threatens to engulf the prairies, the answer might be found in the close-up view. You may notice some differences in temperature and/or rainfall.

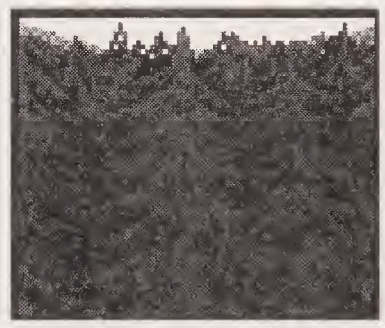
Arctic



Desert



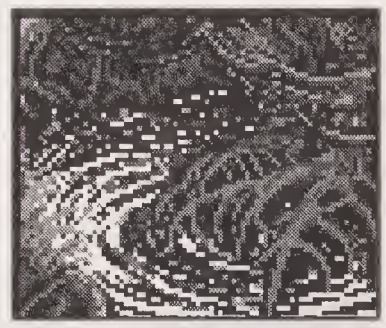
Boreal



Grass

Forest

Swamp

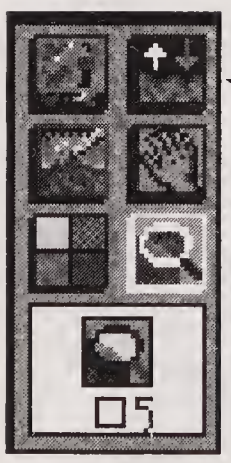


Jungle

Examine the area where one biome begins and another ends, then see which factors change as you examine deeper into one or the other.

	Shelf	Ocean	Deep Sea	Rock	Arctic	Boreal	Desert	Grass	Forest	Jungle	Swamp
Prokaryote	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
Eukaryote	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
Radiate	✓	✓	✓	✗	✗	✗	✗	✗	✗	✓	✓
Arthropod	✓	✓	✗	✗	✗	✗	✗	✗	✗	✓	✓
Mollusk	✓	✓	✗	✗	✗	✗	✗	✗	✗	✓	✓
Fish	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
Cetacean	✓	✓	✗	✗	✗	✗	✗	✗	✗	✓	✗
Trichordate	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
Insect	✓	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
Amphibian	✓	✗	✗	✗	✗	✓	✗	✓	✓	✓	✓
Reptile	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
Dinosaur	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
Avian	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
Mammal	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓
Carnifern	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓	✓

We've reprinted this chart from the SimEarth Manual to show you where your creatures like to live and where they don't.



Set Altitude

Set Altitude

For 50 EU, you can change the altitude of the land on your planet. This tool has no equivalent in the real world. It's simply a convenient tool you can use to affect the land areas of your planet. Each click on the tool changes its effect. For instance, if it is set to raise land, clicking once on it will change it to lower land. Once the appropriate setting is made,

simply click and hold the mouse button down on the place in the Edit window you want to change. The longer you hold down the button, the more the effect will be. Be careful you don't hold it down too long, or you may create an 18,000 foot, sky-hugging peak, or a deep sea trench without intending to do so. Also keep in mind that the Set Altitude tool doesn't just affect the area you click in. The surrounding land also changes. Otherwise, you'd just be creating giant mesas and impossibly deep wells!

The Secret Raise/Lower Oceans Trick (Mac)

On the Macintosh only, you can raise and lower the levels of the oceans on your planet. It's a secret trick. To do it, hold down the Option key and then click and hold on the Raise/Lower Land icon in the Edit window control panel. A small slider bar should appear to the left of the icon. Now, without releasing the mouse button, move up or down. Your oceans will rise or fall depending on the direction you move the mouse. Be careful, though. You could easily flood your world and kill all land life, or you could dry it up and kill everything. Also, in our experience, there's a slight chance that the computer will bomb when using this trick, so don't do it on a planet you haven't saved unless you don't care.

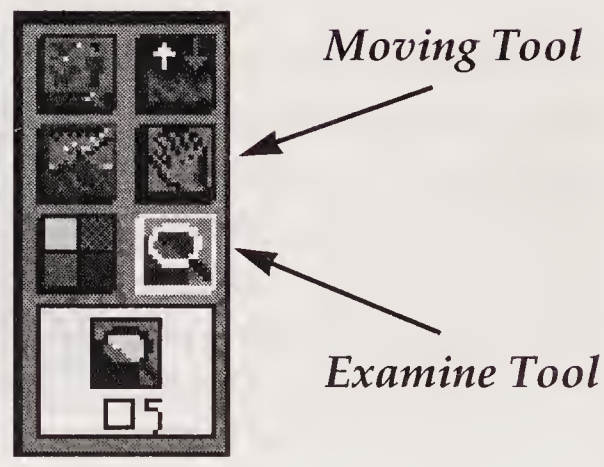
This trick is not like the Show/Hide Oceans button on the Map and Edit windows. It doesn't simply hide the ocean. It actually, permanently changes the ocean level. So use it with caution.

The Moving Tool

The Moving tool is useful for moving an object from one position on the map to another. You can move creature niches, biomes, or cities. Simply click on it, drag the mouse to a new location, and let go. At 30 EU, it is often cheaper to move something than to place a new one on the planet's surface. For instance, if you move a piece of grassland for 30 EU, it will likely be replaced by more grassland in the area it came from (think of it as a sort of Gaia skin graft). On the other hand, placing a new grass biome costs 50 EU. Such a deal!

The Examine Tool

The Examine tool (or Magnifying Glass) lets you get a close-up view of small areas of the planet. It shows you the biome,



Deforestation

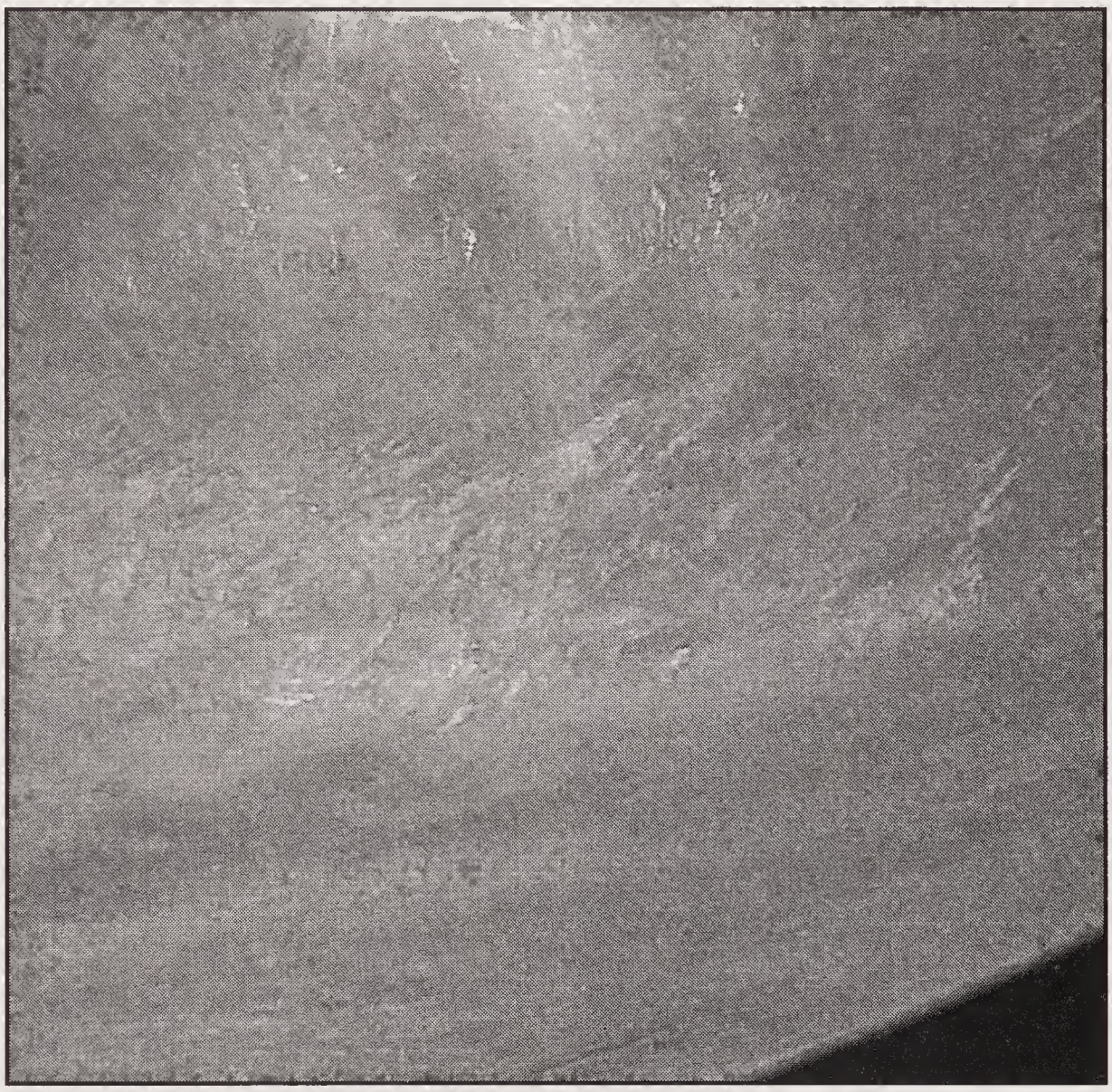
The world used to be covered with forests. Even places we now think of as natural open spaces were once dense forests. For instance, if you drive through Spain, you see rolling hills and plains with scrubby trees and little else. Whole areas look that way, and yet, a thousand years ago, these were great forests. The forests were taken away, used to build cities and boats and to burn as fuelwood. Today, if nobody told you they had been there, you would suppose that this was just a fairly barren land. There's no evidence that the forests ever existed, except in the historical records.

And what about today? The story of the Spanish forests is not unique. All over the planet are areas that once were forested and are now clear scrublands. These places have developed new ecosystems and we take them for granted. However, there are a few places left that have not been destroyed. In fact, the densest and most important forests of the world still exist—for the most part. But in the past 30 years or so, they have been steadily shrinking at an alarming pace.

The greenest part of the Earth extends around the equatorial area from Africa to South America to Southeast Asia. It is this area, representing just 8 to 10 percent of the Earth's land, that contains more than half its plant and animal species. While scientists have named about 1.5 million species so far, they estimate that the rainforests alone may contain anywhere from 5 to as many as 30 million species of plants and animals. Obviously, most of them are completely unknown to us. Some may even exist in very isolated areas. The cutting down of ten acres of rainforest could, perhaps, destroy forever a species of plant or animal. Is that a tragedy? On more than one account, the answer is yes.

Each species is unique and valuable as a miracle of life and evolution. But from our point of view, each species may have something to teach us. Most of our modern medicines were first encountered in natural sources. Many people believe that the medicinal value of the undiscovered life in the rainforests alone is worth saving them. Who knows which obscure plant or animal may provide the secret to curing cancer? Or

Slash and burn.



Deforestation in Rondalia, Brazil. This picture shows plumes of smoke from several fires, each of which would be considered a major forest fire in the U.S.

AIDS? A single example is the rosy periwinkle which led researchers to a way to save children with leukemia. One estimate states that three-quarters of the children suffering from that disease have been saved by this one discovery. Another is the birth control pill, which traces its parentage back to a wild yam in Guatemala. Of course, there are other famous cases including quinine which is used to treat malaria, and curare, a deadly poison which is used in modern medicine. Both came from the rainforests. In fact, it has been said that up to one in four medications we use today was originally discovered in the tropical rainforests.

Of course our own personal needs as human beings may be dwarfed by the overall importance of the rainforests to the global ecology. Rainforests are unique. They create their own world and atmosphere. They create their own cloud cover and rainfall, and they use and reuse nearly all the nutrients and water available. Very little is wasted in a healthy tropical rainforest. Because of this, and contrary to what popular opinion might state, tropical rainforests survive in very thin, poor soil. Cutting down these lush, green, wet worlds to grow human crops or to graze cattle for the excessive meat demands of the northern countries (particularly the U.S.) is both ironic and dangerous for several reasons.

First, because the soil supporting the rainforest is so poor, the resulting agricultural land is also poor. It's not like creating a new Iowa or Kansas. In fact, as we shall see, it may be more like creating a new Sahara. Look at the effect of cutting down the forest canopy. It exposes the poor soil to the most intense heat and sunlight on Earth. It dries it. Moreover, now that the rainforest is no longer there to create the incredible clouds of moisture and rainfall that are a direct result of its existence, the area dries out. Hot winds blow and erode what is left of the soil. Without cloud cover and rain, the tropical areas could warm by 3 to 5 degrees. Combined with greenhouse effects already warming the planet, this might be enough to destroy what remains of the forests—the parts spared man's direct intervention. The result could well be a depleted desert where once stood the greatest biological wonder on the Earth.

Smoke rises from fires in Zaire while thunderstorms have developed in the smoke-filled air.

Destroying the rainforests is also dangerous because of the greenhouse effect. That's because the trees of the forests have locked tremendous amounts of carbon in their cells. Burning and decay will release that carbon into the atmosphere, further compounding an already critical situation. For instance, a tropical rainforest typically holds more than six times the carbon that a cow pasture holds. Changing from one to the other releases most of the free carbon into the atmosphere. So, if the destruction of the rainforests isn't bad enough for other reasons, it certainly will contribute to the Global Warming.

Nobody really understands the interconnections between the forests and the rest of the world. We do know that the forests are important. We also know that they are being destroyed at alarming rates—as much as 30 acres per minute, 24 hours a day according to some reports. In a year, an area roughly the size of England is lost.

The answers and solutions aren't easy to come by. Many of them are the same as the answers to all our global concerns. Some specific situations demand specific actions. However, much of what we have to do is determined not by one crisis or another, but by the total situation.

One simple action most of us can take is to plant a tree. Sounds pretty basic, but every tree is a carbon sink, an oxygen creator, and a shade source that can even reduce the use of air conditioners in hot areas and therefore save fuel. Planting trees doesn't take a government decision. Anyone can do it.

John Robbins, author of *Diet for a New America*, says that if we, in the rich North, were to eat less beef, we could reduce demand and thereby reduce deforestation in the South. However, the answers may not be just that simple. There are economic pressures at work, and much of the deforestation of the world is to accommodate runaway populations, to

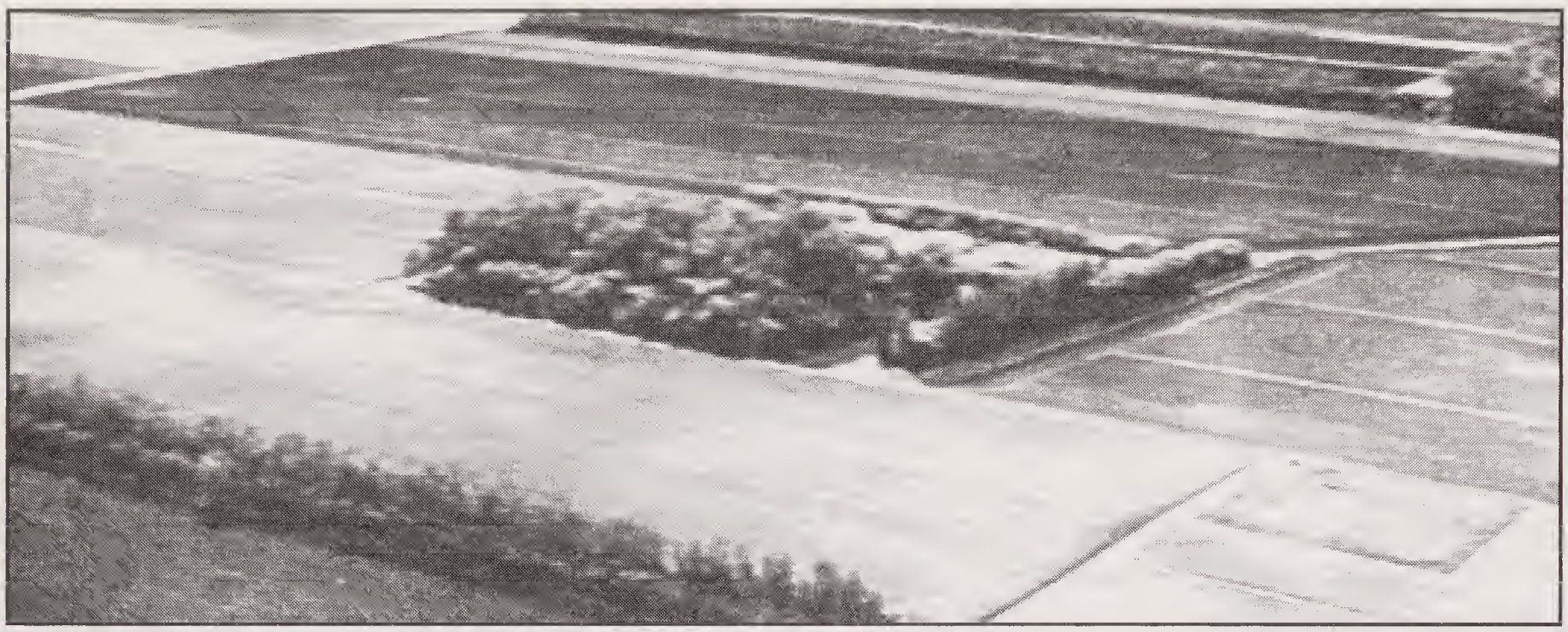
feed and house them and to provide fuelwood, which is still the major source of energy for much of the world.

Part of the answer may involve a greater sharing of technology and resources between the affluent countries in the northern hemisphere and those poorer places in the South. For one example, there are more efficient energy sources than fuelwood, but the poorer countries can't afford them. We can. Fresh water is a dwindling resource, and clean water, proper waste disposal, and disease control are all serious problems in developing countries. Yet the lack of these facilities, often combined with food shortages, means high infant and child mortality. When a family stands a very good chance of losing children to starvation or disease, they tend to have many children. It's a law of survival. If they could count on good, undiseased water, sanitary conditions, and good medical treatment, many of those people would be willing to listen to arguments about limited population growth and birth control. It is ironic that the countries experiencing the most rampant population growth are also those who can least afford it. But it isn't just a coincidence or an accident.

What else can be done? One important, and already well publicized action is recycling. We waste tremendous amounts of our own resources, then have to buy them from other countries. And often, just to survive, these countries sell off their precious resources to the richer countries. The end result is detrimental to everyone, and only benefits anyone in the very short term. However, recycling is probably not enough. We have to rethink our consumption patterns. And we can do that. In areas where droughts hit hard, people learn quickly to do with less water. They find alternatives to the wasteful procedures they had used in abundant times. It might be advisable for us all to consider the probability that a serious resource crisis already exists, and begin now to demand more efficiency, not only from ourselves, but from our governments and industries.

In the end, if we don't consider our world as one and all its people equal, we will suffer the consequences. Even if we do change our approach, we have already set in motion some serious and dangerous situations. There's really no time to sit and wonder. We don't have to abandon technology; that would be a mistake. But we have to change our outlook. It's time for a kinder, gentler, and more efficient and fair world.

Hillsides like this one, cleared of forest cover, will soon erode in the rain and wind.



The Island Effect

As man encroaches more and more on the world, with populations building higher and higher, his effect on the planet increases. In so many ways, we impact the environment that is our home. And yet, we try. We cut down forests, but we try to leave wooded areas and so-called greenbelts. We build cities, but we put parks inside them. What we are doing is building islands of nature in a world of agriculture and urbanization. Our agriculture simply doesn't produce the kind of biomass that natural forests do. And yet we leave precious little forest behind us.

Perhaps we feel justified. Sure, we have to cut down forests to grow crops and build homes and offices, but we leave some. We know how important the natural world is. Sure we do. But what most people don't take into account is the island effect.

The island effect is based on the work of two ecologists, E. O. Wilson and Robert MacArthur, who calculated survival predictions for species on islands based on the size of the island and its distance from the mainland. These calculations have immense impact on our future, even though the reasons may not seem immediately obvious.

There are lots of islands, and not all are in the sea. Any ecosystem that is isolated and bounded by areas not hospitable to it can be considered an island. A special species of plant, the Silversword, grows only at the tops of Hawaii's highest volcanoes. It can't grow lower on the slopes, and it has no mechanism to migrate anywhere else. It lives in an island, and its ecosystem is very fragile.

There are many other natural examples of island ecologies. For instance, for a fish, a lake is an island. For a particular high-altitude tree, an isolated mountaintop may be an island. But much of nature evolved in what would more accurately be considered mainlands because the size and extent of the biosystem is large enough so that the potential dangers of extinction due to natural or artificial disaster is not so devastating. For instance, what might happen to the lone tree species on the mountain top if there were a large fire? It might be wiped out. But in the Amazon, a forest fire, even though it were as large as the state of New Jersey, would not wipe out the forest. Many such fires, happening every day might, but that's a different story.

The Amazon is being used as a great laboratory to explore the island effect. Under the guidance of another ecologist, Thomas Lovejoy, sections of the Amazon rainforests are being protected. These sections vary in size from a couple of acres to a couple of hundred acres. Plans include the formation of more islands, one more than twenty thousand acres.

The early experiments showed the island effect all too dramatically. At first, many birds flew into the area seeking sanctuary from their disappearing ecosystems. These were the refugees looking for a place to roost.

Within six months, the population of refugees began to disappear. At the same time, the trees at the edges of the island began to die. They weren't used to the intense sunlight, having evolved and grown in the dense forest, protected under the canopy formed by all the other trees. Now, suddenly exposed to the raw sunlight and wind, they simply began to die off from the edges. The island was getting smaller.

Many animals, especially those used to ranging across a large territory, simply disappeared while others stayed and ate all the available food in the limited territory left to them, then they, too, disappeared. In many other surprising and disturbing ways, species disappeared and the island became smaller and less diverse.

In the Amazon, this is a truly significant finding. It means that the continued destruction of the rainforest is going to have a terrible effect, even if patches of the forest are left intact. In fact, in Brazil there is a law that prevents a farmer from cutting down more than half the forest on his land. Even if this were enforced, it would probably not do much good, but it is not enforced. Farmers simply buy and sell the land, and each new owner gains the right to cut down another half. It's a loophole that spells trouble for the most productive region on the planet.

But the island effect isn't limited to the Amazon. It is happening all over the world. The natural forests are rapidly being pushed into small, unviable regions that won't be able to recover from natural and unnatural events. One such event might be a change in the overall temperature of the Earth, something that is happening now and is called Global Warming.

What happens when the temperature changes in a region? Normally, species will migrate, seeking appropriate conditions. For instance, a tree that normally favors the temperate regions of the plains may find its environment becomes too hot. What does it do? It may find cooler climes to the north, or perhaps higher on a mountain. But if it is a very small island of trees in an urbanized or agricultural area, how will it move? The great forests can adjust, the puny outposts of nature we have left behind cannot. Any uprooting effect will have its casualties. When the population is small to begin with, its chances are small.

The chances for the survival of any ecosystem probably depend on how fast the Global Warming happens. If it is very gradual, then many species may survive as they adapt to the slow changes. But if it follows the predictions of many scientists, our planet may experience a change so dramatic that it will warm twenty to forty times faster than it did after the last ice age. The most likely survivors will be the traditional opportunists—weeds, rats, cockroaches, flies, crows, and so on.

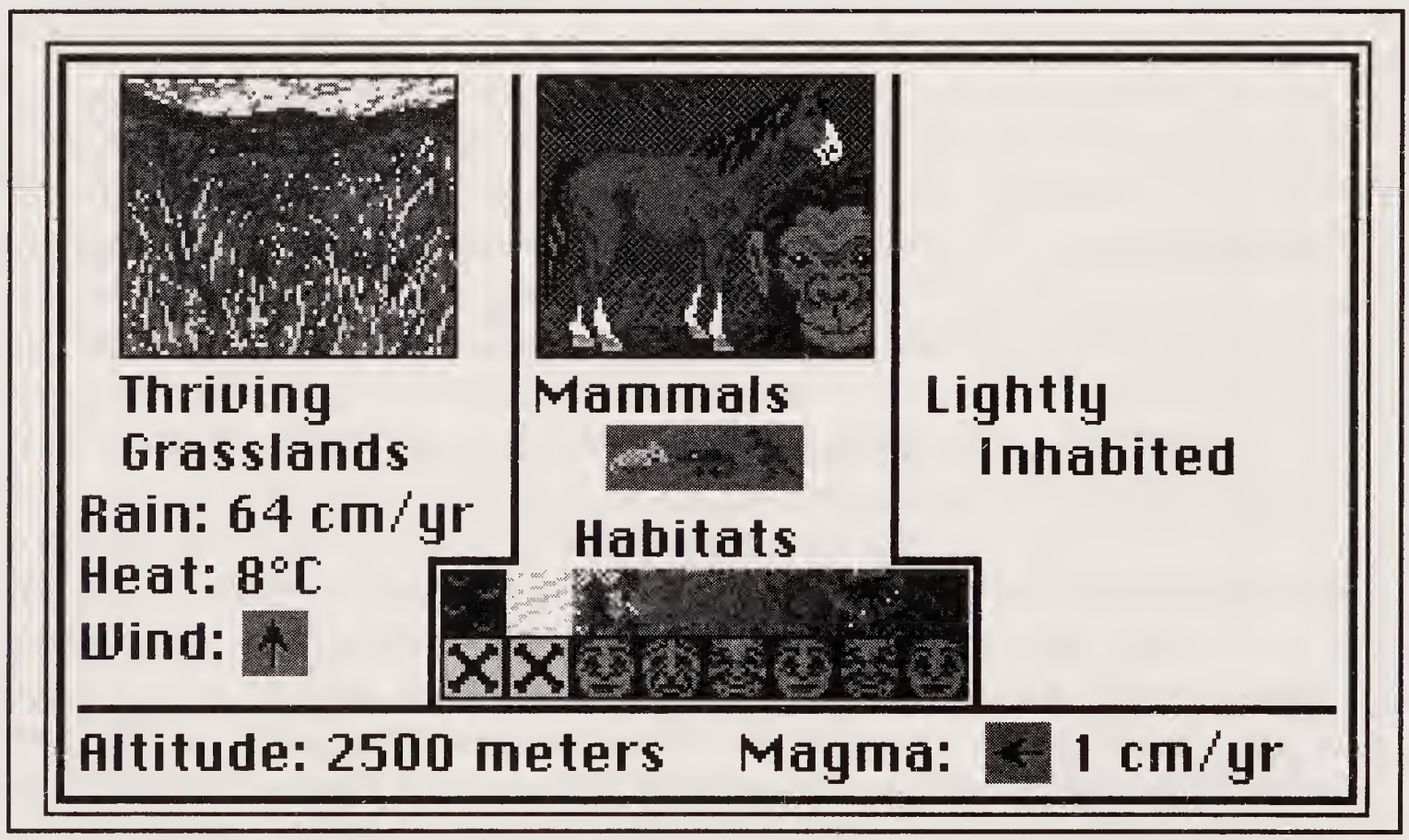
There's much more to this island effect. It impacts the climate of the Earth and all of us upon it. As we sacrifice more and more of our natural land to our plundering, we threaten not only the natural world we love, but ourselves as well.

Always remember the distinction between contribution and commitment. Take the matter of bacon and eggs. The chicken makes a contribution. The pig makes a commitment.

—John Mack Carter

the life in that area, any civilization present, as well as information about the local altitude and magma flow. Choose the Magnifying Glass icon, then click anywhere in the Edit window display area. Hold down the mouse and drag it around to see information about other areas. Each time you click and let go, it costs 5 EU.

If you hold down the Shift key (the Help mode) and click in the Edit window display area, you'll also see the same information shown by the Examine tool. However, the cost in EU of using the Help mode may vary depending on what has been selected in the Edit window control panel. This is true on the Macintosh and may be true on other versions of SimEarth. Therefore, always use the Examine tool to get a close-up view of the display area.



The Examine window that displays when you use the Examine tool consists of four sections—the Biome Section, the Life Section, the City Section, and the Altitude/Magma Section.

The Biome Section

In the Biome Section, you'll see what kind of biome is under the icon along with a picture of it, how well it's doing (thriving or dying), the current rainfall, heat, and wind direction. There is no indicator for wind velocity.

The Life Section

In the Life Section, you see a picture of any life present, what it is, and what its habitats are. Below the species name are three smaller pictures. The one on the left represents the form the species recently evolved from. The middle picture is its present stage of evolution, and the right picture is its next evolutionary stage.

In the habitat graph, the icons represent how well the creature can survive in a particular habitat. These conditions range from not at all, to miserable, to adequate, to paradisiacal. See the chart on page 136.

The City Section

In the City Section, you'll see information about any civilization present in the examined area. If there is no city, but there are sapients present, the window will read "Lightly Inhabited." If there is a city, a picture of the city will appear and a description of the kind of sentient life present, its level of technology, and its local population. Moving populations are treated as moving cities.

The Altitude/Magma Section

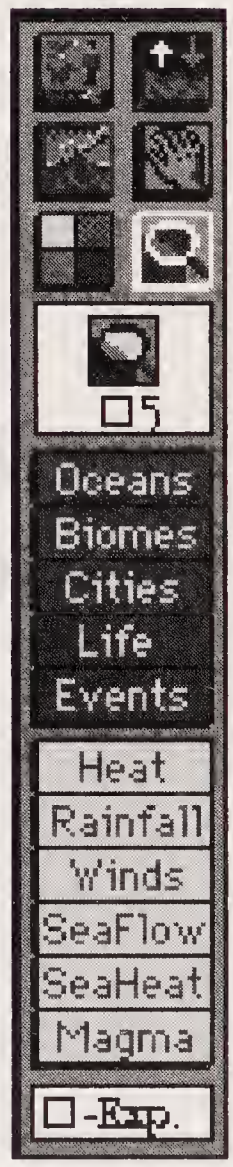
Displays information about the local altitude and the direction and speed of magma flow.

The Current Tool Display

This display shows the current tool selected from the palette of icons above it. Be sure to check the current tool (and its cost in EU) before clicking in the display area of the Edit window. On the Macintosh this is especially critical because just clicking in the display area activates the current tool—even if the Edit window is not the active one. This is also true when working in MultiFinder, where clicking in the display area of the Edit window activates the current tool, even if it isn't the active application!

The Data Layer Buttons

The Data Layer buttons allow you to display different parts of the model without in any way affecting the model itself. For instance, you can turn off all life if you want to see the biomes alone. Or turn off the oceans to see the land underneath.



Current Tool Display.

Data Layer Buttons.

Climate Layer Buttons.

Energy Units.

In each time scale, different data layers are automatically turned on and off. Naturally, during the Geologic period, Biomes and Cities are off. During the Evolution time scale, everything is on except Cities. And during the Civilization and Technology time scales, everything is on except the Life data layer, which would unduly clutter the Edit window image if not turned off. However, you can turn it back on again.

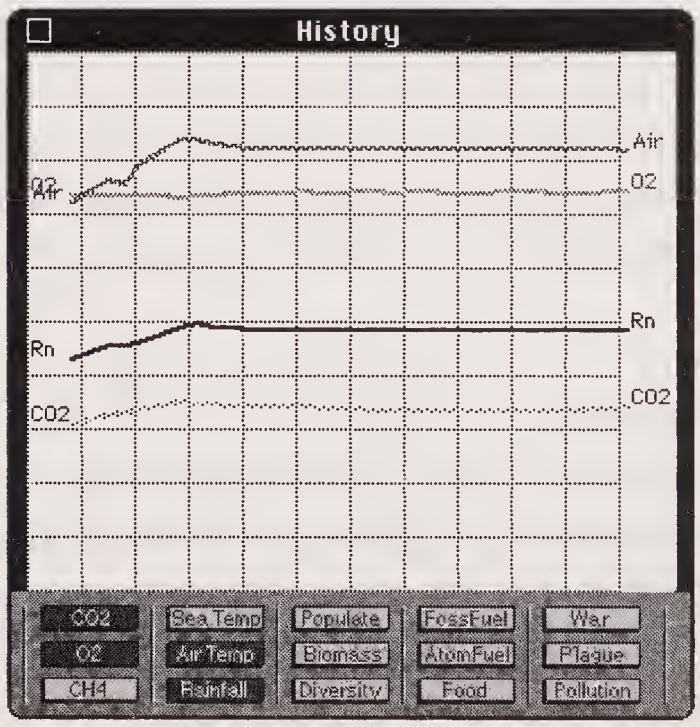
The Climate Overlay Buttons

Like the Data Layer buttons, the Climate Overlay buttons are toggles—they turn on and off with each click. Use these buttons to get a local view of the same kinds of information you see in the Map window on a global scale: Heat (Air Temperature), Rainfall, Wind Direction, Sea Flow, Sea Heat, and Magma flow. If you are familiar with their counterparts on the Map window display, these overlays should be easily understood. Only turn them on when you need to see what they offer. They tend to obscure the rest of the map.

The Available Energy Display

When you play one of the limited energy models (Easy, Average, Hard), this shows the amount of EU you have remaining. The energy replenishes over time. In the Experimental mode, you have unlimited energy and the display shows an infinity symbol.

THE HISTORY WINDOW



The History window provides a graphical image of your planet's performance over time. For each of fifteen different categories, you can view a running line graph. Because the graph updates in real time, the History window is a great place to monitor the changes taking place on your

world. It may provide the first indication that a catastrophic event is taking place, or it may be where you confirm your suspicions about the events you're observing. If there's room on your screen, keeping the History window open at all times is a good idea.

Whenever a new time scale begins, a vertical bar appears to mark the beginning of that period. You'll notice an instability in the model during the switch from one time scale to another. This is not always a true indicator of likely real events, but is sometimes an anomaly of the computer model. For instance, the planet will heat up when switching from the Geologic to the Evolution time scale. This is an artifact of the computer model. However, it will soon begin to cool as plants suck carbon dioxide from the atmosphere, and an ice age will result. This may be closer to fact. Scientists now believe that ice ages have occurred in regular cycles of 100,000, 43,000, 24,000, and 19,500 years.

The History window is particularly useful for tracking such parameters as air temperature, oxygen and carbon dioxide levels, rainfall, biomass, population, and so forth. During the course of history, you may need to view different parameters. Just remember, the History window gives you not only the current data, but the past trends. You can often use it to explain trends that you don't understand. For instance, suppose your population is falling. Checking the History window, you might find out that plagues have been rising sharply for some time. Or you might find there's very little food.

The History window tracks information about 15 different parameters. It can display graphs for up to four of these parameters at a time. You can mix and match your graphic displays any way you want, changing the mixture at will.

The History window tracks the following data:

- **CO_2** — The amount of carbon dioxide in the atmosphere.
- **O_2** — The amount of oxygen in the atmosphere.
- **CH_4** — The amount of methane in the atmosphere.

- **Sea Temperature** — The average ocean temperature.
- **Air Temperature** — The average air temperature.
- **Rainfall** — The average planetary rainfall.
- **Population** — The current population of sentient life.
- **Biomass** — The current total weight of plant and animal life. Because 95% of the planetary biomass is plant material, this is a good indicator of the relative health of the plant world.
- **Diversity** — The number of different species on the planet. If conditions are bad and many species are dying off, this line will dip. Even though biomass might stay high, diversity can fall off. A planet with a higher diversity is more healthy.
- **Fossil Fuels** — The amount of fossil fuels available. This graph should grow during the Evolution time scale as plant matter decays and turns into fossil fuels. Once civilization begins to use those fuels, though, the graph will fall pretty fast.
- **Atomic Fuel** — The amount of atomic fuel available on the planet. This amount falls as civilization uses nuclear power.
- **Food** — The amount of food being produced on the planet. In real life,

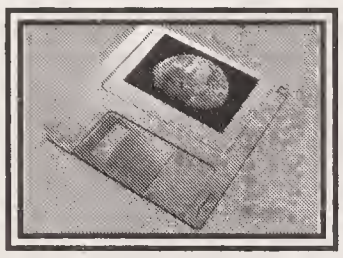
this number may be high, but unequal distribution can mean that millions starve in the midst of plenty. In SimEarth, such distribution problems don't exist.

- **War** — An indicator of the number of wars breaking out on your planet. You may see periods of relative quiet with large outbreaks from time to time.
- **Plague** — An indicator of the outbreak of serious epidemic disease on your planet. Like wars, plagues can occur cyclically and can sometimes peak during major epidemics.
- **Pollution** — An indicator of the amount of pollution by your civilization. This may rise sharply during the Industrial Age, depending on your choices.

History Window Time Spans

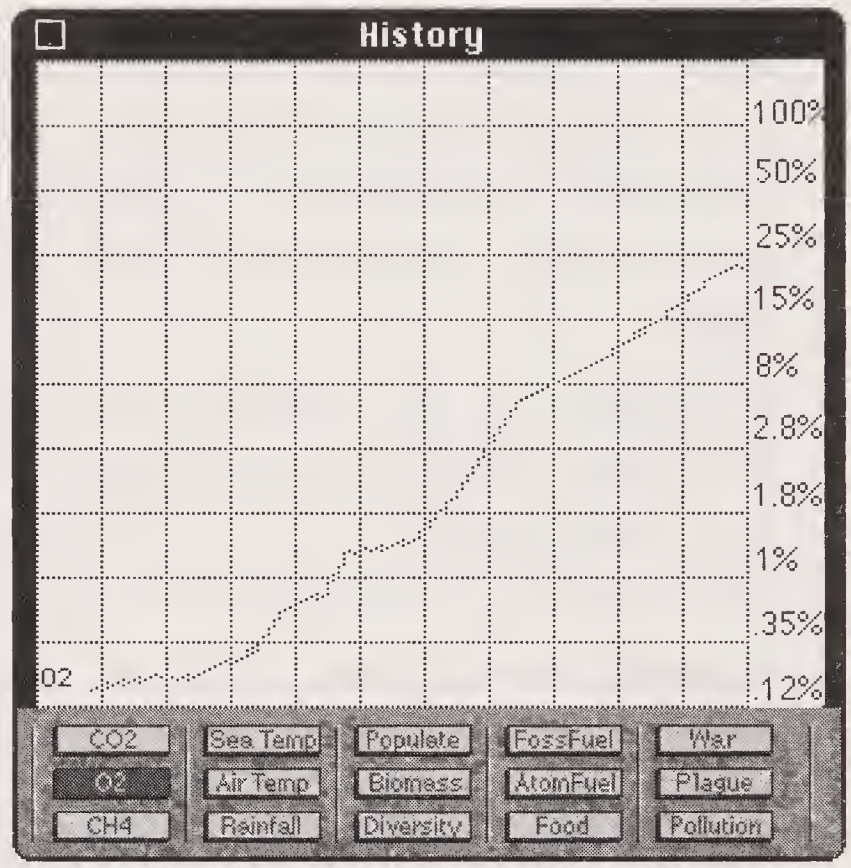
Period	Total Time (years)	Each Division (years)
Geologic	1,000,000,000	@90,000,000
Evolution	70,000,000	@6,4000,000
Civilization	2,500	@227
Technology	50	@4.55

The time divisions in the History window vary with the time scale your planet is currently in. For instance, during the Geologic time period, the total window covers one billion years. With eleven divisions, this means that each division is approximately 90 million years. See the chart for information about all the time periods.

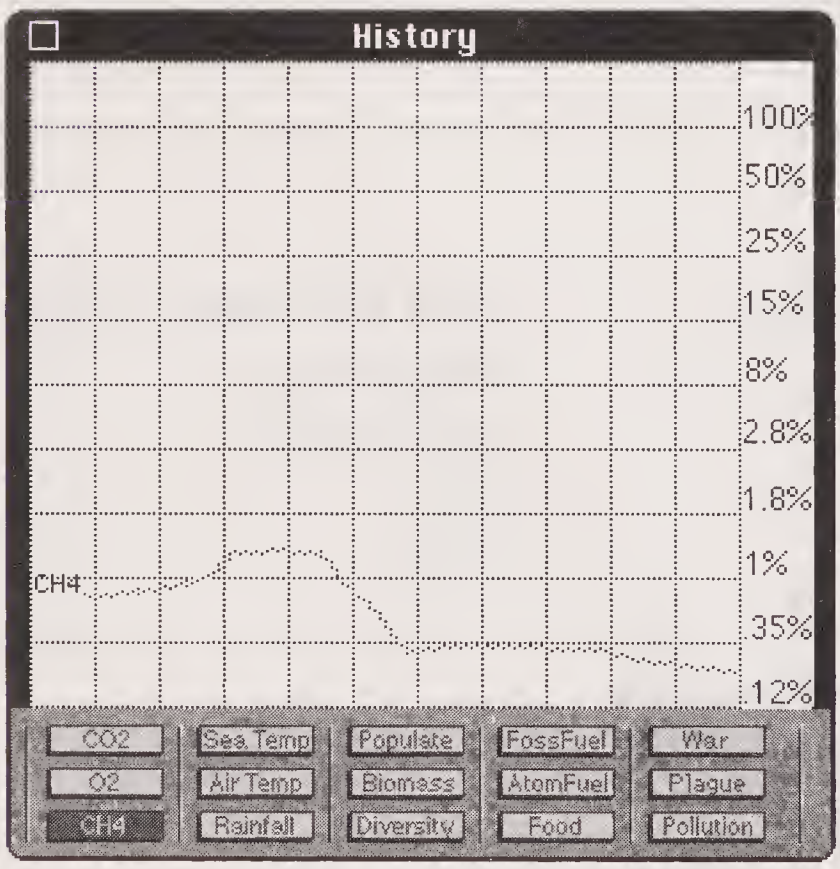


History Windows

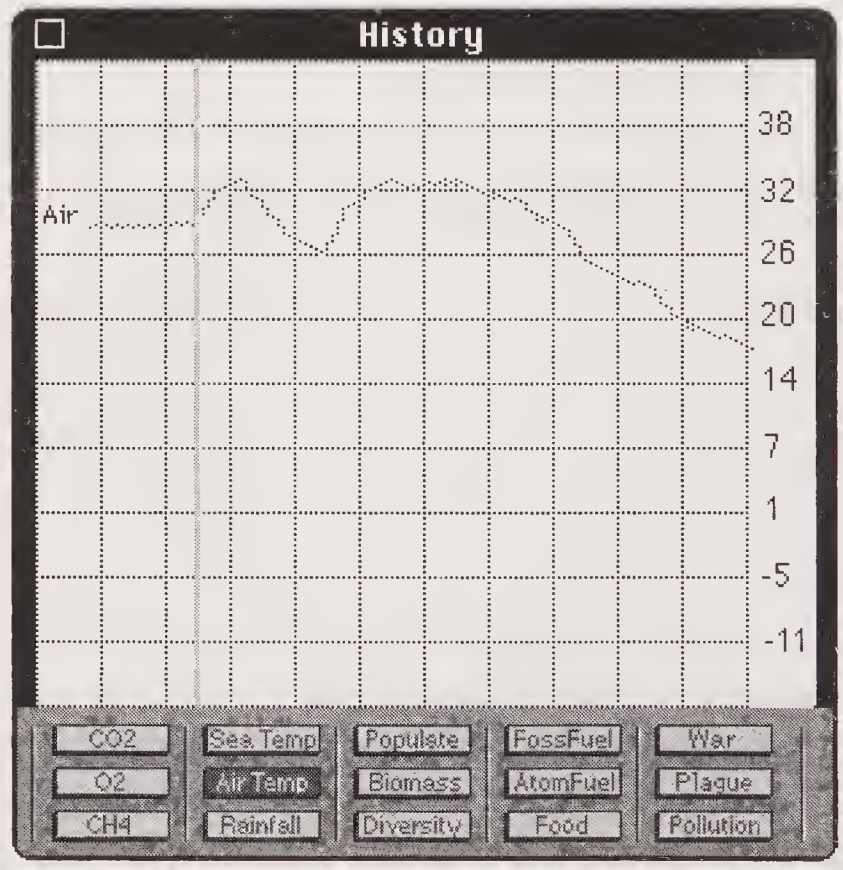
The CO_2 Graph



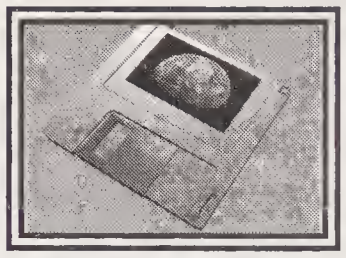
The O_2 Graph



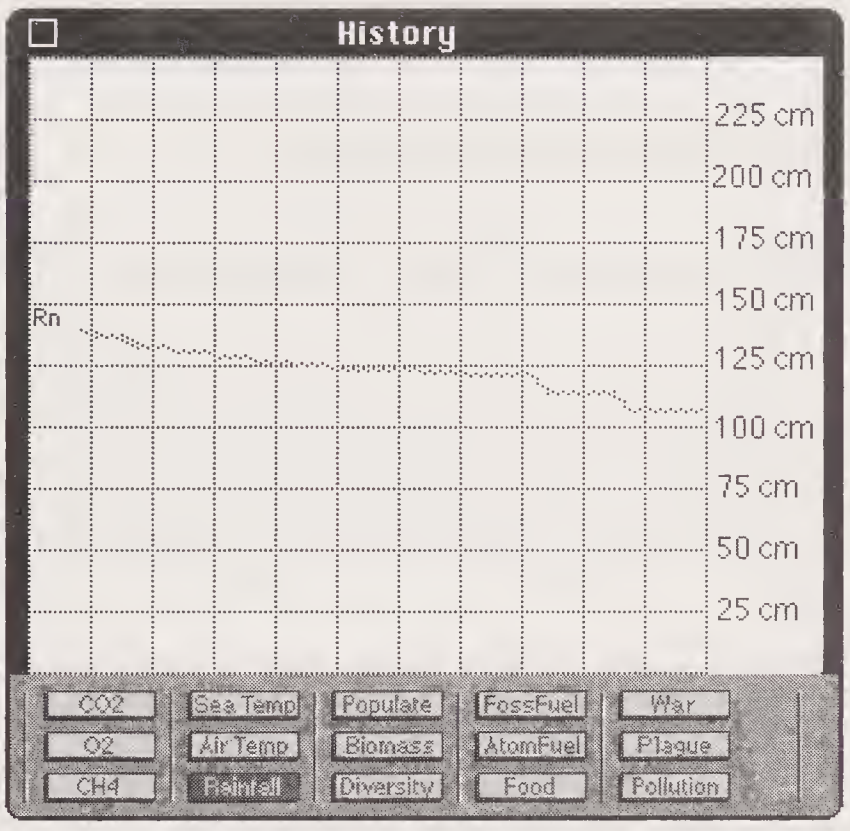
The CH_4 Graph



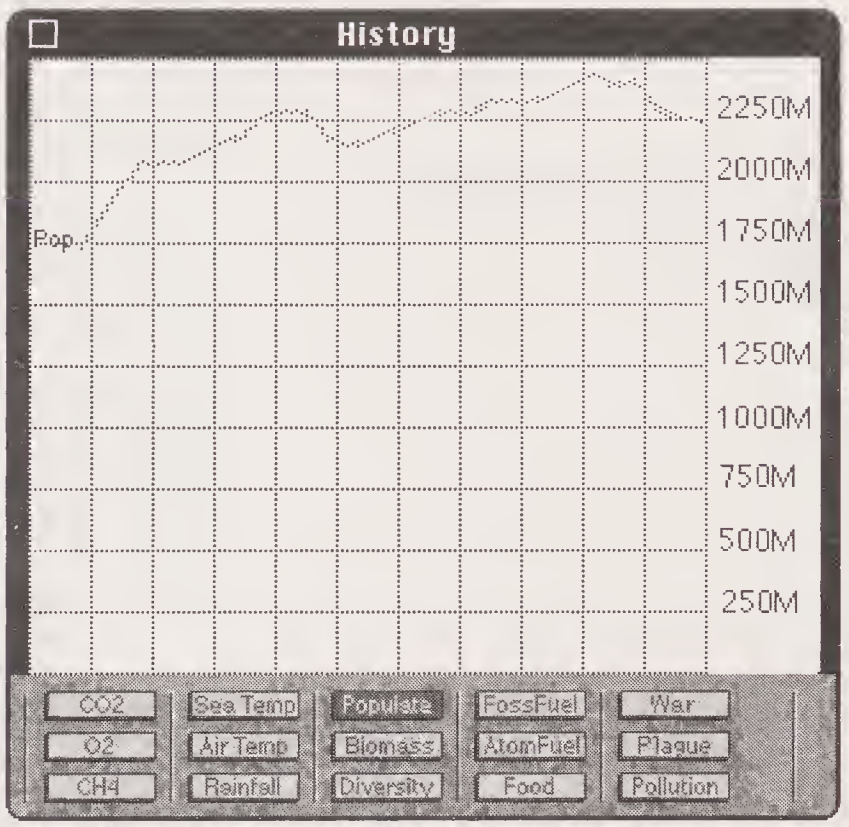
The Air Temperature Graph. (Values are the same for the Sea Temp. graph).



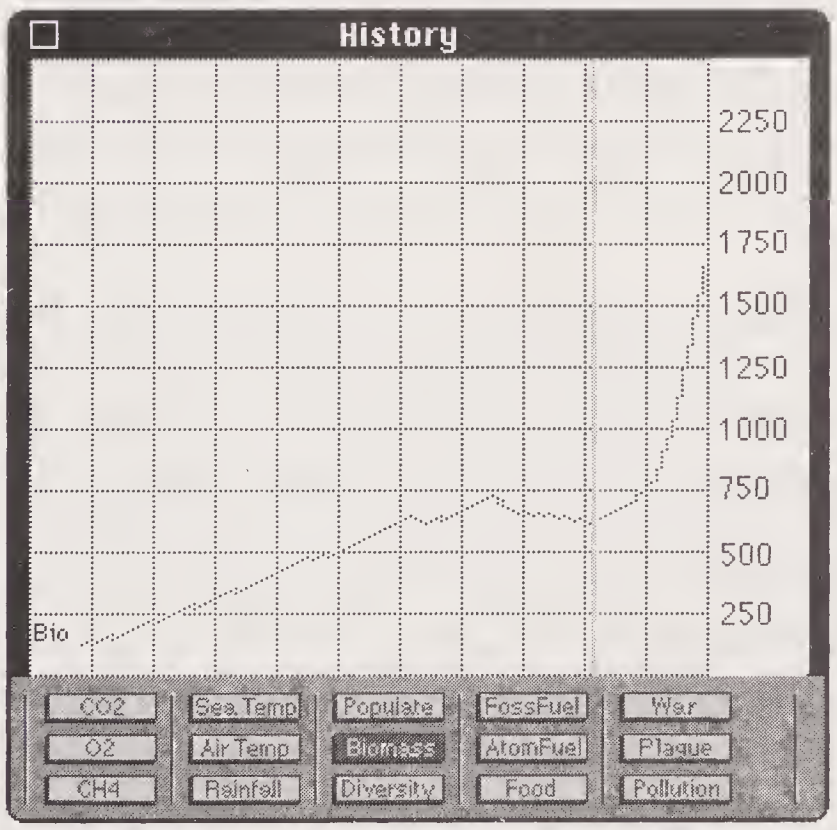
More History Windows



The Rainfall Graph (cm/yr).



The Population Graph (millions).



The Biomass Graph (millions of tons).

The other graphs are not based on exact numbers—relative values only.

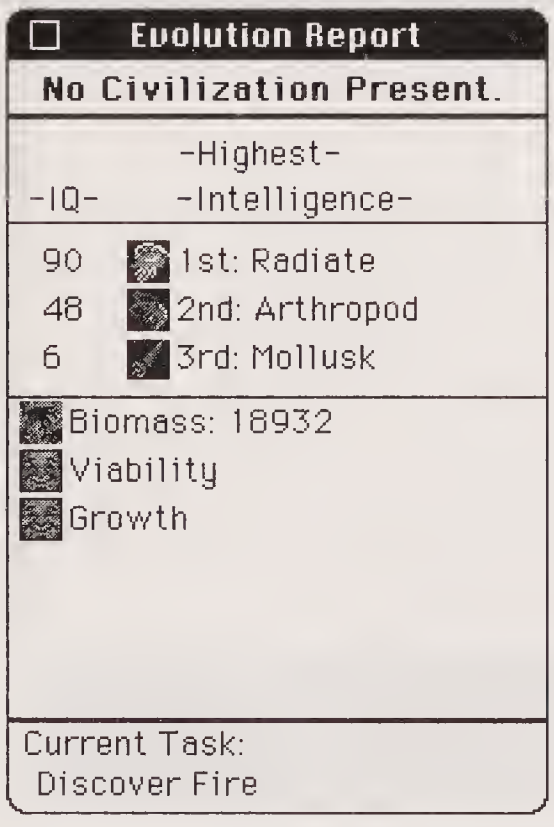
THE REPORT WINDOWS

The Report window is actually six different windows, depending on the time scale and the simulation you are running. In each time scale or simulation, the report tells you about the current task (which may or may not be your personal goal) and the general state of life on the planet.

The Geologic Report Window

In the Geologic period, the Report window shows the basic viability of the planet (how suitable is it for life?), the highest life form (if any), and the biomass of the planet (if any). The biomass is a good indicator of the viability of the planet. If its level is growing, then life on the planet is expanding. If it is falling, some conditions must be blocking the spread of life, since, in the Geologic period, the world is wide open to the colonization of life.

The Current Task of the Geologic time scale is to develop multicellular life. There are other events that must take place before this will happen, but that is the ultimate task that will catapult the planet to the next step in its evolution as a living biosystem.



The Evolution Report Window

The Evolution Report window displays, somewhat unnecessarily, that there is no civilization present. This is redundant since if civilization were present, this would be the Civilization Report window, but I guess they just want you to be sure.

In addition to this piece of useless information, the Evolution Report does tell you what species have so far evolved the highest intelligence levels. The top three (if there are that many) species are ranked and their relative SimIQ is listed as well. A species with an IQ of 90 is pretty close to evolving a civilization. However, some species can teeter on the verge of civilization for quite a while, especially if conditions don't favor their discovery of fire (as in the case of creatures who prefer water habitats).

In general, a more advanced species on the evolution scale has a better chance of reaching the top of this list than a less advanced one, but the first creatures to evolve have a head start. Thus, early in the Evolution time scale, radiates

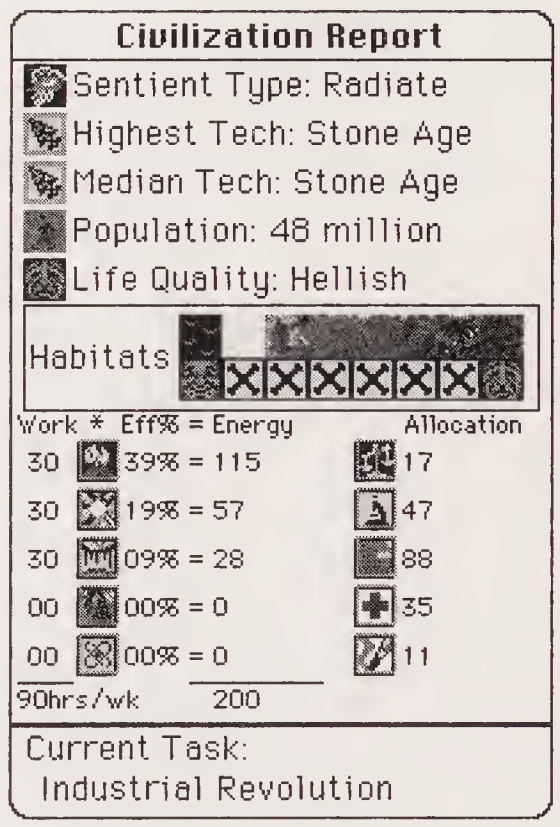
may be at the top of the list while other, more advanced creatures that show up later will be lower in the intelligence scale. However, given time, they will supplant the radiates.

The Evolution Report also shows a figure for Biomass, another icon for Viability, and a new icon for Growth, which shows, essentially, the conditions for the growth of new biomass (plants) due to the availability of CO_2 in the atmosphere.

Finally, the task of this time scale is to discover fire, a sure indicator of civilization in this model.

The Civilization and Technology Report Windows

The Report windows for Civilization and for Technology time scales are exactly the same. They feature a lot more information than previous Report windows. The first section deals with the state of the civilization.



Sentient Type — The type of sentient creature (mammal, reptile, dinosaur, carnifern, etc.).

Highest Technology — The highest level of technology on the planet.

Median Technology — Actually shows the dominant technology, not necessarily the statistical median.

Population — Shows the population figures for the sentient race on the planet. This figure is a critical indicator of the success of a species, and should be watched closely.

Life Quality — The general conditions of your "people." Life Quality can range from Heavenly to Hellish with several in-between states (Good, Pleasant, Tolerable, Unpleasant, Bad, and Miserable). Life Quality is generally a function of the amount of work hours the civilization must perform each week and the total population, though it is influenced by the settings for Arts/Media in the Civilization Model window.

Habitats — Shows each biome type (including water) and displays an icon to represent whether the civilized species can thrive in that environment or not.

In advanced civilizations, it may be possible for a species to build cities in biomes they normally couldn't inhabit. For instance, Nanotech Age civilizations can build cities in the oceans.

The Energy Section

The second section of the Civilization/Technology Report shows how work is converted into available energy. It lists each of the available energy sources, the number of weekly work hours devoted to these sources, and the amount of energy derived from them. An energy efficiency rating is assigned to each level of technology, and that efficiency affects the amount of useable energy produced. For instance, an Atomic Age civilization is far more efficient at converting work into energy than a Stone Age one would be.

At the bottom of the column is the total work hours per week and the total energy generated.

How much work is invested in each energy source is determined by the Civilization Model Control Panel. The higher the bar for each energy source, the more work is invested in that source.

Bioenergy is the burning of wood, the use of animals, farming, and manual labor by the citizens of the civilization.

Solar/Wind power is used in various ways, including using the sun to dry food and clothing, windmills, sailboats, solar heating, and more modern methods like photo-voltaic cells, satellite collectors, and more.

Hydro/Geo is the use of water and earth power.

Fossil Fuels are oil, coal, and gas created by the decay of animals and plants that died millions of years ago.

Nuclear power is derived from the energy released during the decay of radioactive substances.

* For more information about energy sources, see also the Civilization Model Control Panel

Opposite the work-to-energy equation is a list of the allocation of the energy that has been generated. This allocation is determined by the settings in the Civilization Model Control Panel. The higher the setting for an individual energy use, the more of the available energy will be allocated to it. The five activities that receive the energy are Philosophy, Science, Agriculture, Medicine, and Art/Media. The bars in the Civilization Model Control Panel do not represent exact amounts, but relative allocations. Therefore, if all five bars are at their maximum, an equal amount of available energy will be allocated to each one. If they are all at the halfway point, exactly the same amount of energy will be allocated. However, if one is longer than another, the longer one will receive a proportionately greater share of the available energy.

Philosophy creates a more thoughtful race; one that does not rush into war.

Science is the key to technological advancement, and so is necessary for your civilization to get past its current state of development.

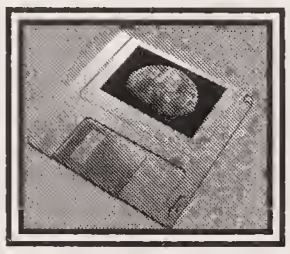
Agriculture is probably the most important use of energy for an emerging civilization. Without food, they can't expand. With plenty of food, their numbers increase incrementally—even if conditions are otherwise miserable, there are numerous wars, and plagues are epidemic.

Medicine is important in preventing and curing plagues.

Art/Media is the setting for the finer things in life.

* For more information about energy allocation, see also the Civilization Model Control Panel

Finally, the Current Task of the Civilization time scale is to reach the Industrial Revolution, and the Current Task of the Technology time scale is to reach Exodus to the stars.



How Societies Advance

The way civilization develops in the SimEarth model depends on the amount of energy produced by a civilization. Each "tick," the total amount of Science energy the Sims produce is lowered by 20% and added to a rolling sum of previous energy values. Eventually, if the civilization reaches consistently high levels of Science energy production, they will advance to the next level of technology. The chart shows how much energy is needed (in the hidden sum) to reach the next level. The second value shows the approximate total energy production per tick needed. This figure will vary greatly depending on the Science setting.

Civilizations will advance at different rates. For instance, if the Science setting on the Civilization Model Control Panel is high, the Sims will advance faster. If it is low, they will advance slower. And, as usual, there's plenty of randomization to make predictions nearly impossible. Still, the information in these charts should help a little.

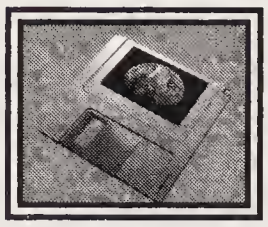
At first, you may have a hard time getting budding civilizations to prosper. However, with patience and a little luck, your creatures will eventually reach the stars.

Chart of Energy Requirements for Technological Advancement

Tech Level	Hidden Sum	Energy Produced
Bronze	> 200	@200-400
Iron	600	@550-800
Industrial	6000	@6000-7500
Atomic	10,000	@10,000-12,000
Info	20,000	@20,000 or more
Nano	30,000	@30,000 or more
Exodus	80,000	@60,000 or more

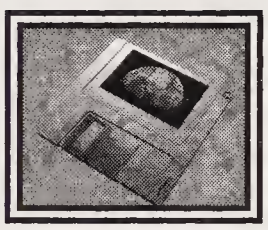
Chart of Energy Efficiency by Technology (averaged)

Tech Level	BioEnergy	Solar/Wind	Hydro/Geo	Fossil Fuel	Nuclear
Stone	40%	20%	10%	0%	0%
Bronze	40%	20%	30%	10%	0%
Iron	60%	20%	30%	30%	0%
Industrial	60%	30%	50%	80%	10%
Atomic	70%	50%	50%	80%	80%
Info	80%	60%	60%	90%	90%
Nano	90%	80%	80%	90%	90%



Energy Unit Replacement by Tech. Level

Tech Level	Increase Rate
Stone	2/cycle
Bronze	3/cycle
Iron	4/cycle
Industrial	5/cycle
Atomic	6/cycle
Info	7/cycle
Nano	8/cycle

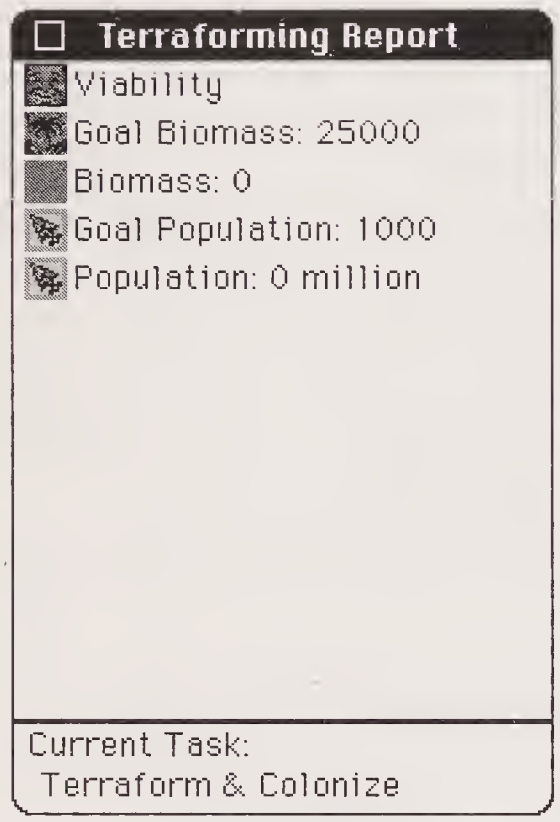


City and Traveling Icons

	City	*Land*	*Sea*
Stone Age			
Bronze Age			
Iron Age			
Industrial Age			
Atomic Age			
Info Age			
Nanotech			

The Daisyworld Report Window

The Daisyworld Report is pretty simple. It shows you the dominant (or most common) daisy, the amount of empty space remaining for daisy colonization, the major animal (if present), and the Current Task (which is to raise daisies).



The Terraforming Report Window

The Terraforming Report is much like the Civilization/Technology Report with a few changes.

Viability tells you how generally friendly the world is to life. This information is based on the levels of oxygen and dust in the atmosphere.

Goal Biomass tells you how much biomass you need to develop in order to consider the job of terraforming accomplished.

Biomass shows how much biomass is currently on the planet. The icon that displays with this figure shows which biome is the most common.

Goal Population is the number of people who must inhabit the planet for you to succeed at your task.

Population is the current population of the planet.

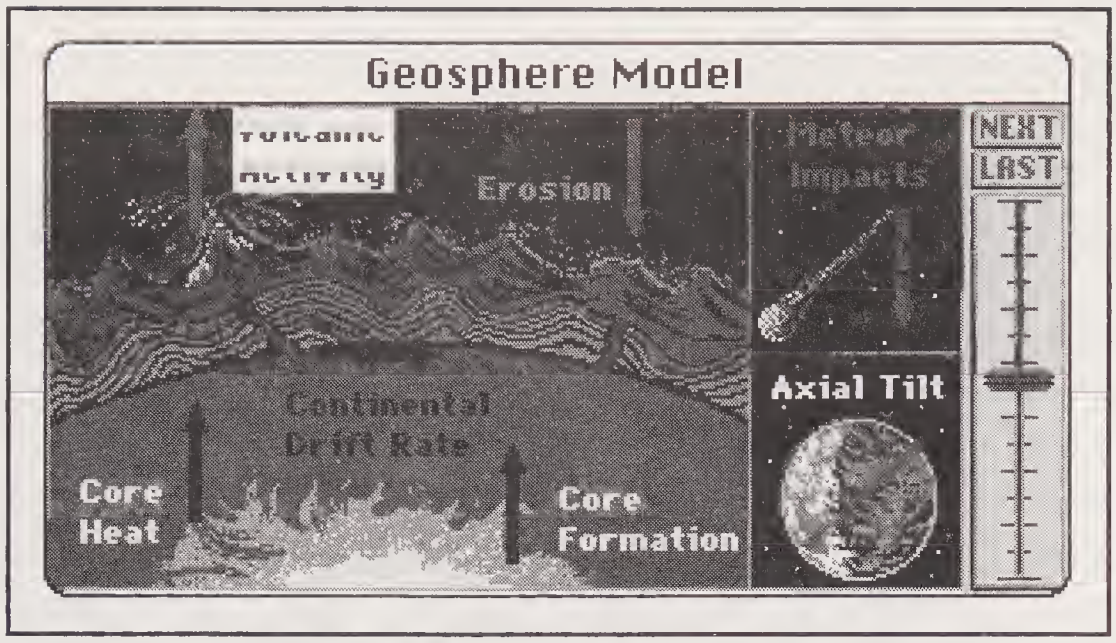
Habitats shows the available habitats for mammals (the only species that is considered intelligent in the terraforming models). This information will not appear until there is sentient life on the planet.

The **Energy** section of this report is the same as it is in the Civilization/Technology Report (detailed above).

The **Current Task** is to terraform and colonize.

THE MODEL CONTROL PANELS

The four Model Control Panels are powerful tools that affect your planet on a global level. Changes made in these control panels can have far-reaching effects, and even small changes can create powerful ramifications. Therefore, learning to use the tools in these windows is important to effective management of certain aspects of the simulation.



The Geosphere Model Control Panel

Open the Geosphere Model Control Panel by selecting Geosphere from the Models menu or by clicking on the Geosphere button in the Map window.

The Geosphere Model Control Panel consists of seven tools for changing the basic parameters of your world. These are Volcanic Activity, Erosion, Continental Drift, Core Heat, Core Formation, Meteor Impact, and Axial Tilt. Use these functions to experiment with different kinds of worlds.

Volcanic Activity

This controls the frequency of volcanic eruptions. Obviously, at the beginning of the planet, volcanism helped build the continental land masses. Later in history, volcanoes still can build new land, but too much volcanism can threaten life by destroying life and cities and by throwing up clouds of dust that block the sun. Try setting Volcanic Activity very high during a civilized period and see what happens to your planet.

Erosion

This controls the forces that wear down the land surfaces. These forces are primarily wind and water (in the forms of rain, rivers, floods, and oceans). Erosion also releases more CO_2 into the atmosphere and is one way to influence the greenhouse effect indirectly.

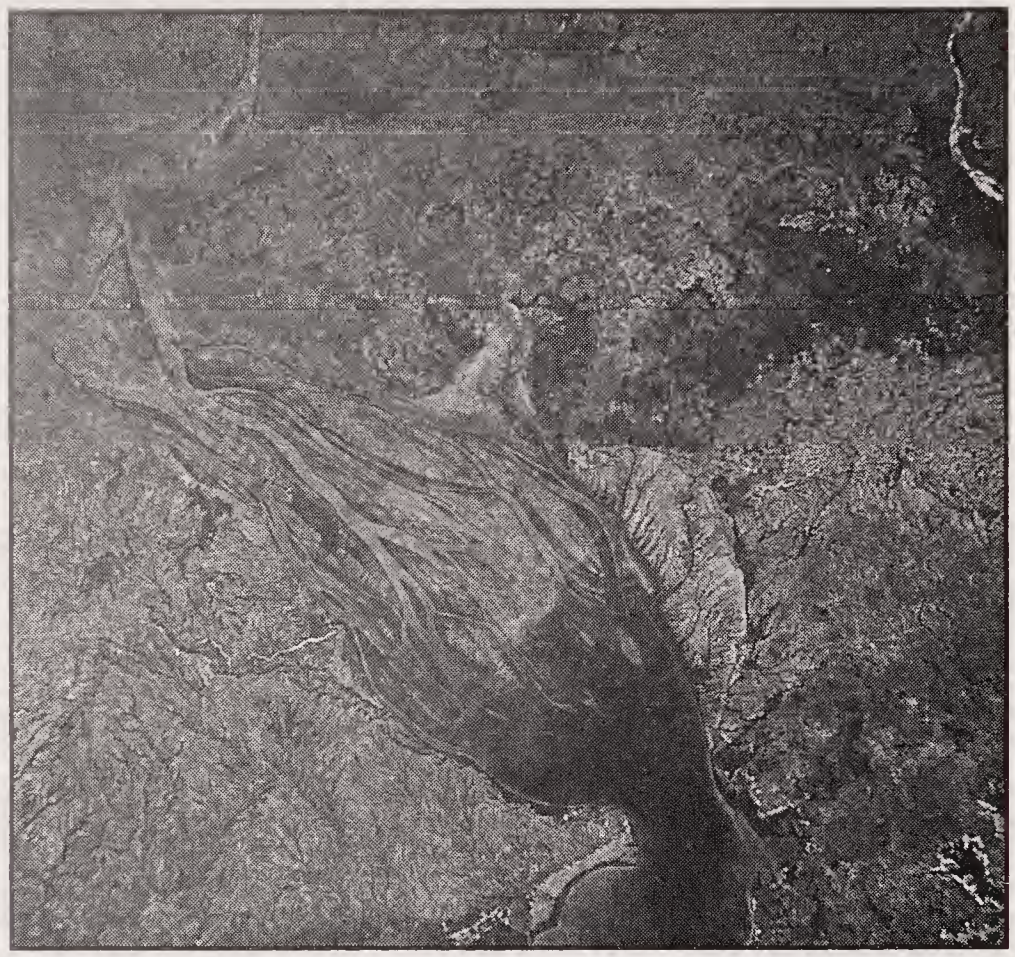
Setting a high erosion factor will smooth out your continents, reducing high elevations and causing a lot of land to run off into the oceans. A world with high Erosion would have a lot of low land areas and large continental shelves.

Erosion, Desertification, and Agriculture

In SimEarth, you can simply turn up the allocation to agriculture in the Civilization Model Control Panel. With the Agriculture setting at the maximum, people just have so much food, they keep reproducing faster than just about any disaster can destroy them.

Unfortunately, SimEarth does not make us pay any penalty for this use of agriculture, but the real world does. Current agricultural practices are endangering one of our most precious resources, the topsoil. Deforestation causes serious erosion as the soil, once held by the root structures of the forest floor are now exposed. So clearing land in some areas to grow crops results in loss of soil at alarming rates.

Meanwhile, the U.S. produces food at record rates and exports food all over the world. In principle, this is good, but the cost may be astronomical from a human perspective. Our intensive farming techniques rely increasingly on petrochemical fertilizers. The land itself gets more and more worn out, and the U.S. alone loses more than 700,000 acres of topsoil and arable land each year. Worldwide, the problem is much greater, and some countries are losing their topsoil at incredible rates.



Soil erosion on Madagascar in 1983. Land is being cleared for cattle (Zebu), resulting in massive deforestation.

Erosion and sedimentation in the Betisboka River Delta.

This overcultivation, which squeezes record crops from the land but depletes it and wears it out, is a problem, but it is not the only problem. Overgrazing is also a serious contributor to soil erosion, one that also contributes to another problem—desertification.

Desertification happens when otherwise arable lands become deserts. Although there are natural arid zones on the Earth where

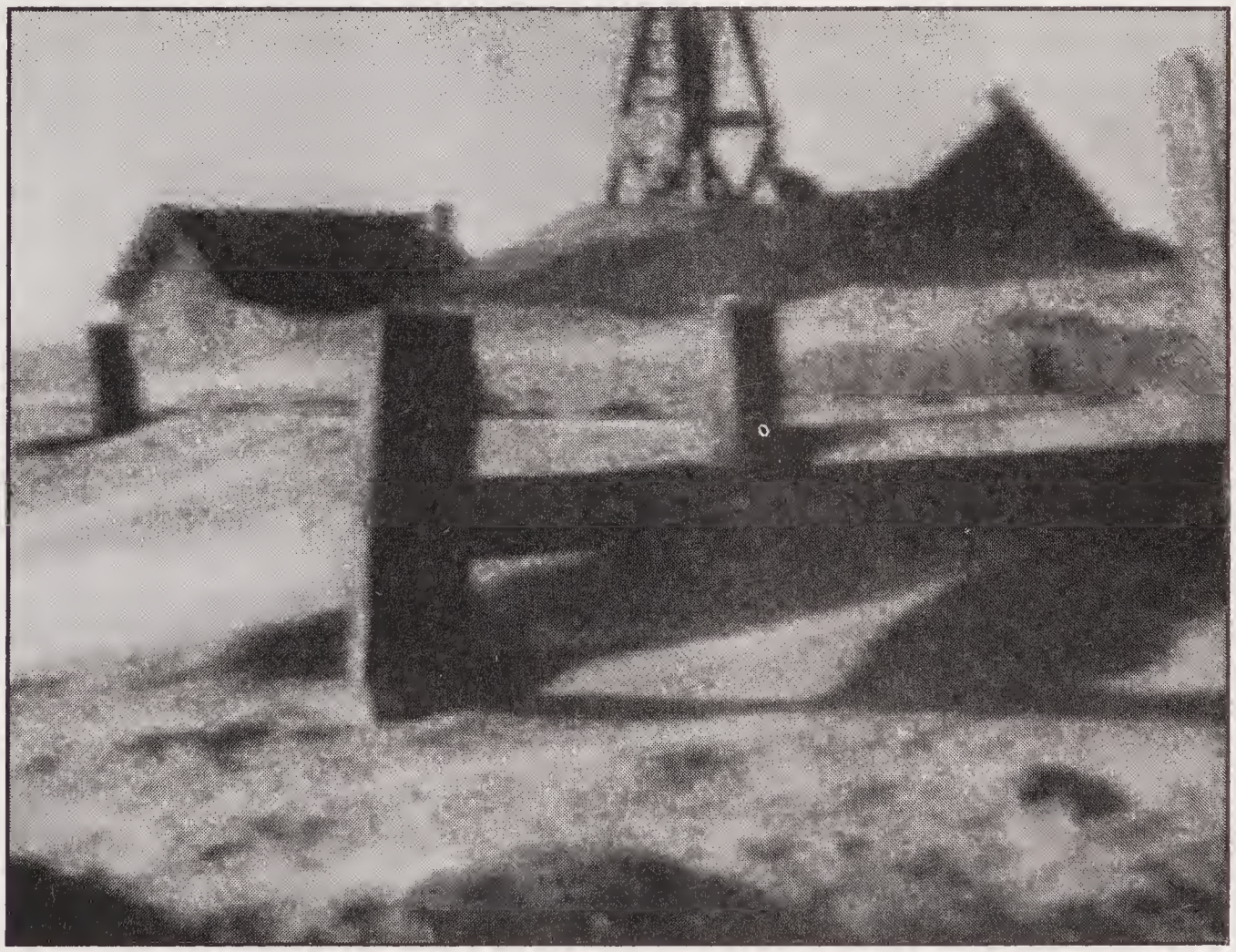
deserts are created by conditions of climate, other areas are becoming deserts due to Man's mismanagement and misunderstanding of the land. When an area becomes desert by natural process, it is called desertization. When the cause is man-induced, the term is desertification. All over the globe, there are regions in danger of becoming agriculturally worthless, more than 30 million acres each year.

There are other problems. For instance, much of the agriculture of the developed world is now controlled by huge corporate entities—agribusiness. Not only do these agribusinesses control the production of food, they also control most of the seed companies and the fertilizer companies, the pesticides, and even the machinery farmers need. The problems in this system are many and varied. For instance, these same agribusinesses are developing and marketing seed strains that are suited only to growing in combination with large applications of fertilizers—those same fertilizers that the agribusiness also produces. To make matters worse, most of these fertilizers are petrochemical in nature, which means they are derived from oil. It is fairly obvious to anyone who is paying attention that oil is one of our least renewable resources and continued dependence on it is just plain stupid. Not only that, but the reliance on petrochemical fertilizers and the kind of intensive farming it produces is not the most efficient practice, though it may be the most profitable for a combine that controls just about every aspect of the process and sells its own products to itself.

There are many possible solutions to the agricultural problems we face. Soil management is being practiced effectively in many places around the planet. In China they feed billions of people on a fraction of the arable land that the rest of the world has available. In Bali they practice a kind of intensive farming that efficiently produces crops while preserving the land. In fact, in many places people have found ways to reclaim desert or near-desert lands and make them productive, without petrochemicals.

Intelligent use of windbreaks and careful management of soil resources can reduce much of the erosion and desertification that is taking place. Feeding the planet need not be a problem, nor must it be at the cost of our precious resources. But it is a matter of careful planning, good education, and better distribution. (See also Cash Crops and Food Distribution).

Erosion gone mad: The Dust Bowl.



If you fail to plan, you are planning to fail.
—Anonymous

This may be a healthy planet, but it could be susceptible to floods as ice caps freeze and thaw, lowering and raising the sea levels.

Continental Drift

This controls the movement of continents as they drift on the magma. With Continental Drift set high, the continents will move rapidly and easily on the magma. Think of this setting as a grease gun for the continents. With more lubrication, they move more easily.

With a high setting, the continents will bump around quickly, running into each other and constantly reforming. When continents hit each other, they form mountains like those in the Himalayas which were formed when India (which migrated from way down in the southern hemisphere) crashed into Asia. The result was to form the highest mountains on Earth. And they're still forming!

Core Heat

This setting lets you change the basic temperature inside the planet. With higher heat in the core, there will be more volcanic activity (so if you want really monster volcanoes, turn up this setting and Volcanic Activity). In addition, the heat of the core will affect the rate of change in the magma flow. A higher setting will cause continental drift to change directions more often.

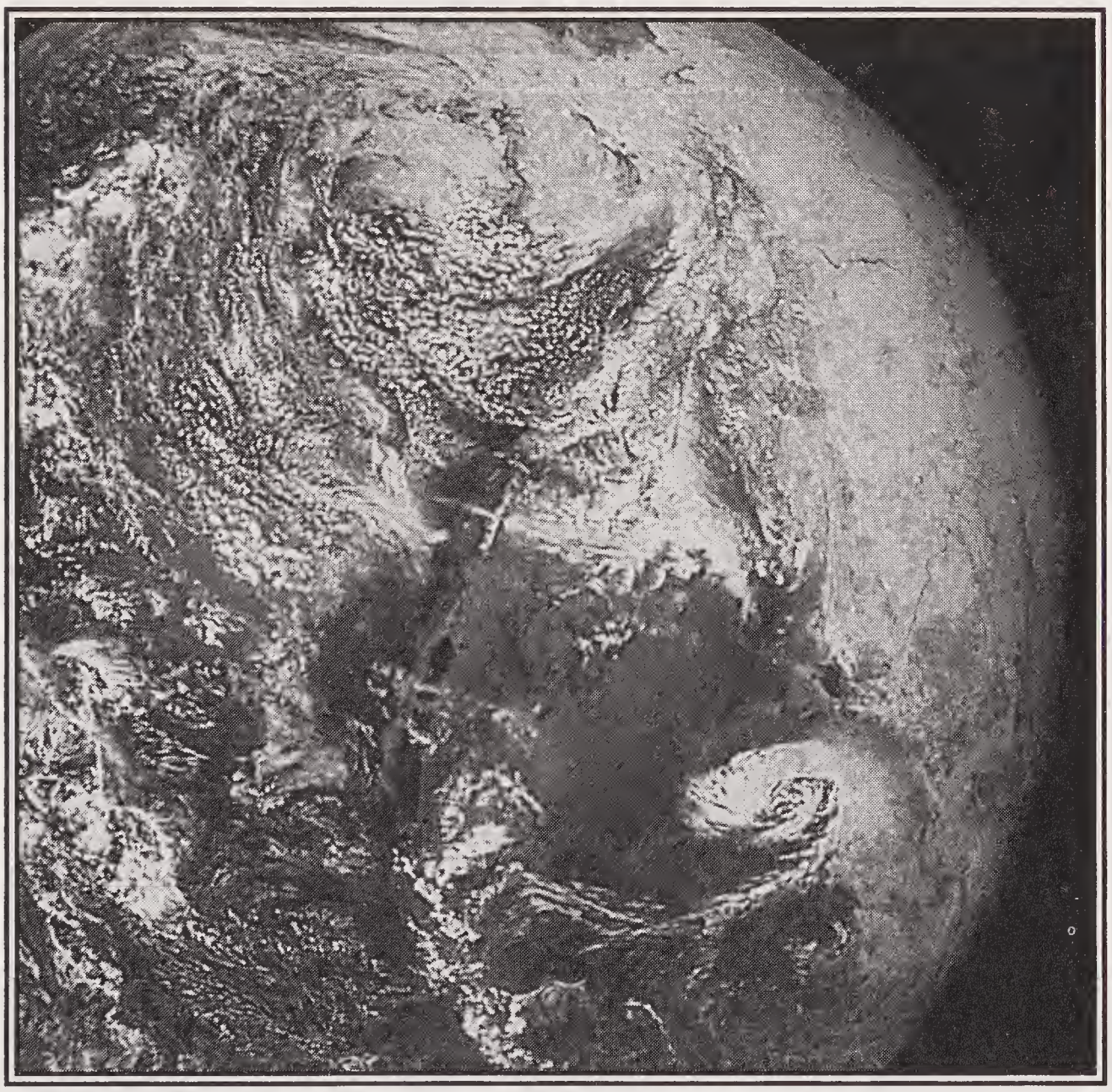
Core Formation

This indirectly controls the size of the core and thereby the size of volcanoes and the rate of continental drift. If the Core Formation setting is high, then the core becomes larger. A larger core means slower moving magma. So a high Core Formation setting will result in smaller volcanoes and slower continental drift.

For the maximum geologic activity, turn Volcanic Activity, Core Heat, and Continental Drift rate very high and Core Formation very low. Things will really move around, however the planet that eventually evolves will probably not be very viable. You may even be surprised at the eventual results.

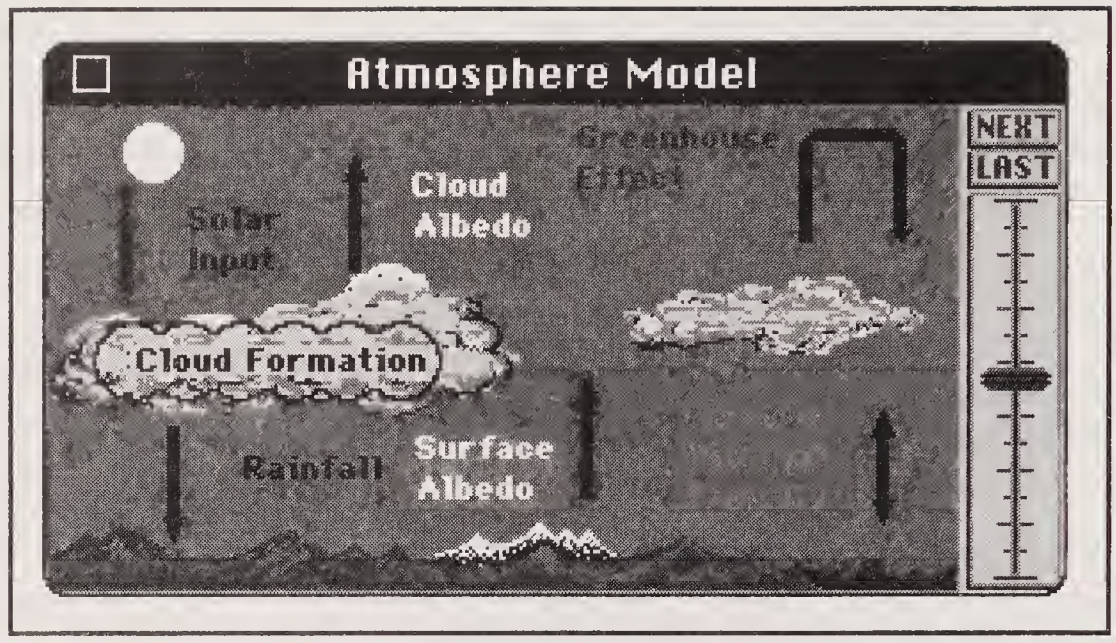
Meteor Impact

This affects the frequency with which meteors strike the surface of the planet. Meteors can reshape the land, change the direction of magma flow, and also affect the atmosphere. When a meteor hits land, it will carve away a deep crater, perhaps creating a lake, and it will also throw dust into the air, perhaps affecting the amount of sunlight that reaches the planetary surface. When a meteor hits water, it throws water vapor into the atmosphere, increasing rainfall and perhaps increasing the greenhouse effect a little. It also causes tidal waves that can destroy coastal settlements. In either case, magma flow direction should change.

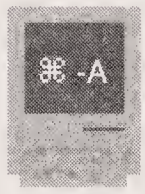


Axial Tilt

This controls the angle at which your planet faces the Sun. The greater the amount of tilt, the greater will be the effect of seasons on your planet. This only affects the simulation during the Civilization and Technology time scales. These are the only scales slow enough to register seasonal differences.



The Atmosphere Model Control Panel



Open the Atmosphere Model Control Panel by selecting Atmosphere from the Models menu or by clicking on the Atmosphere button in the Map window. You may also be able to use a keyboard shortcut.

The Atmosphere Model Control Panel consists of seven tools—Solar Input, Cloud Albedo, Greenhouse Effect, Cloud Formation, Rainfall, Surface Albedo, and Air-Sea Thermal Transfer.

Solar Input

This controls the amount of heat the planet receives from the Sun. Turning this slider all the way up will most likely boil off the oceans and kill all life. Turning it off is a good way to see what would happen without the Sun. It's not a pretty picture in either case.

Cloud Albedo

Albedo is the amount of reflectivity of an object. This tool lets you determine how much sunlight the clouds will reflect back into space. A high albedo means it will reflect more, thus allowing less light (heat) to reach the surface. A high cloud albedo tends to cool the planet.

Greenhouse Effect

This tool lets you change the amount by which certain gases reflect heat back toward the surface instead of letting it radiate back into space. The greenhouse effect depends on the properties of certain gases—notably carbon dioxide, methane,

The biosphere is as much, or even more, the creation of the Sun as it is a manifestation of earthly process. Ancient religious institutions which regarded terrestrial creatures, especially human beings as "children of the Sun" were much nearer the truth than those which looked upon them as a mere ephemeral creation, a blind and accidental product of matter and earth forces. Terrestrial creatures are the fruit of a long and complicated cosmic process and, subject to predetermined laws, form a necessary part of a harmonious cosmic mechanism in which chance does not exist.

—Vladimir Vernadsky

The Sun is the ultimate source of energy and life. The Earth itself traps much of the Sun's energy, though about 30% is reflected back into space. Solar energy from photosynthesis is the basis of our food chain.

Even though it takes only about 8 minutes for the Sun's light to reach us, it has already been on a 10 million year journey from the center of the star. It is so dense at the center that the particles simply bounce around until they finally come out. By then, they are cooler and carry less energy—fortunately for us. If the raw energy from the Sun's core, at about 15 million degrees Centigrade, were to reach us, there would be no us.

Even so, the Sun's energy dwarfs all man-made energy sources. In fact, it would take 200,000 million million nuclear reactors to equal the Sun's output. And even though we only receive one part in a billion of this energy, that small part is the equivalent of more than 500,000 billion barrels of oil per year. However, our use of solar energy is still much less than one percent of the total oil consumption.

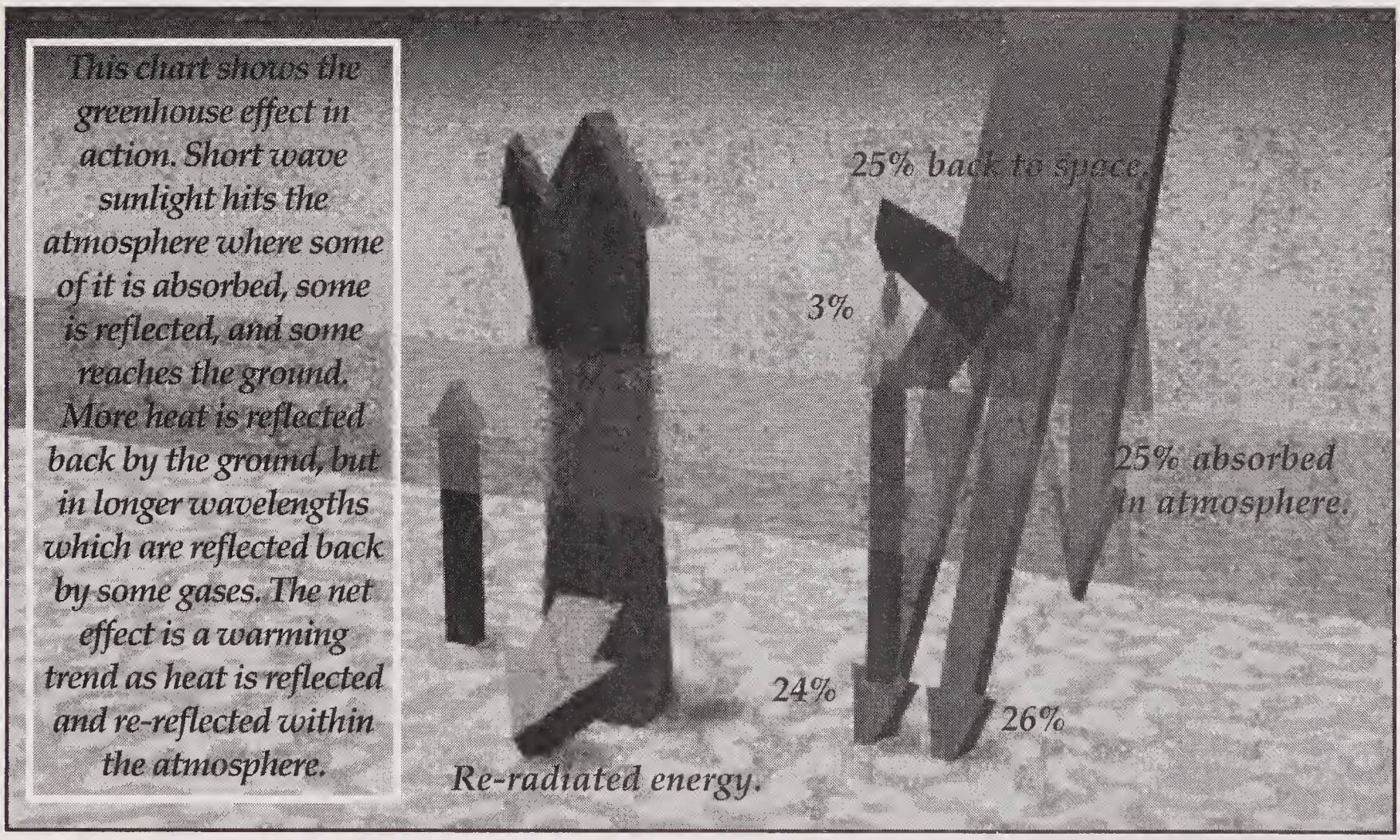
The Greenhouse Effect and Global Warming

One of the most compelling problems we currently face is the so-called Greenhouse Effect and the resulting Global Warming. For years, people have debated the reality of this situation, but it looks more and more like it is real and we're in it.

How does the greenhouse effect work? Basically, certain gases allow the full spectrum of energy from the Sun to reach the Earth, warming the planet and fueling life through photosynthesis. However, some of the energy is re-radiated back toward space as infrared radiation (heat). Molecules with two atoms like oxygen (O_2) or nitrogen (N_2) have no effect on this radiation and allow it to pass unhindered. This means that more than 98% of the planet's atmosphere is completely permeable to the reflected heat. However, certain gases with more than two atoms, notably carbon dioxide (CO_2), interact with the reflected heat in a complex manner. In essence, they vibrate at the wavelength of the infrared, and prevent much of the heat from escaping back into space. The result is a retention of heat.

Carbon dioxide is one of the major greenhouse gases, but it is by no means the only one. One of the worst categories, for several reasons, are man-made. These are the chlorofluorocarbons, otherwise known as CFCs. Although the furor over the hole in the ozone layer caused some nations and companies to cut back on the manufacture and use of CFCs, in reality they are still being produced and used in many industries, including the computer industry where CFC-113 is used as a solvent for cleaning microchips.

The Greenhouse Effect



This chart shows the greenhouse effect in action. Short wave sunlight hits the atmosphere where some of it is absorbed, some is reflected, and some reaches the ground. More heat is reflected back by the ground, but in longer wavelengths which are reflected back by some gases. The net effect is a warming trend as heat is reflected and re-reflected within the atmosphere.

CFCs are powerful greenhouse gases on their own. They last anywhere from 75 to 110 years in the atmosphere and don't break apart until they eventually drift into the stratosphere where ultraviolet radiation breaks them apart. However, then they attack the ozone, but that's yet another problem. One of the most unfortunate effects of CFCs is that they block certain wavelengths of energy that carbon dioxide does let through. In a sense, there is a small window of energy that can escape the effect of carbon dioxide. CFCs close that window, making their effect all the more disturbing.

Methane is also a greenhouse gas twenty times more effective at blocking heat than carbon dioxide. Methane is increasing at about 1 percent per year, twice the rate of carbon dioxide increase. Methane breaks down fairly quickly in the atmosphere, but it forms carbon dioxide and water vapor, both greenhouse gases, when it does so. Also, when methane reaches the stratosphere and breaks down, the water vapors in the coldest parts form tiny ice crystals which have the ability to collect stray chlorine atoms from broken-down CFCs. In combination with the ice crystals, the chlorine atoms are able to eat thousands of times more ozone than they would floating freely. The reason for this is complex, but has to do with reactions that take place in the presence of solid surfaces, like the tiny ice crystals left behind when the methane breaks down.

Methane is produced from a variety of sources, some of which are named in the section on the Atmospheric Composition Graph. The fact that methane levels are building up in our atmosphere is simply one more cause for concern.

The chemistry of the atmosphere is incredibly complex, and many man-made compounds are contributing to the problem. For instance, nitric oxide, not in itself a greenhouse gas, may be playing a very important role in the disturbance of our atmosphere. For an excellent treatment of the situation, I recommend Jonathan Weiner's book, *The Next Hundred Years*, from which I obtained much of this information. Jonathan goes much deeper into the complex interactions of gases and how our history of industry and forestry has contributed to the current situation.

So what does all this mean? So what if there's a greenhouse effect?

As greenhouse gases build up to higher and higher levels, their effects are intensified, and the result should be a gradual warming of the planet. The idea that the planet might warm up by a few degrees may not sound too alarming, but even a global rise of 3 degrees Centigrade could have wide-spread results far beyond expectations.

As Jonathan Weiner explains it in his book *The Next Hundred Years*, a global fall of 3º C would be enough to start an ice age, and a rise of the same amount could start a chain reaction of effects. According to Syukuro Manabe of the Geophysical Fluid Dynamics Laboratory, there would be eight predictable effects:

1. The Troposphere would heat up while the Stratosphere would cool.
2. Warming in the higher latitudes would be several times greater, partly due to the change in albedo from the highly reflective ice and snow to the darker and more absorbent ground. This might actually benefit some areas, but the overall effects would be dangerous and unstable.

3. Winters in the Arctic Ocean would be much warmer while summers would only be a little warmer. Elsewhere on the planet, all seasons would be much warmer.
4. The water cycle would be increased and disrupted so that more water would evaporate and would fall as rain, while other areas might dry out.
5. The polar ice caps would shrink. Scientists don't agree about how fast this might happen and estimates range from decades to centuries before significant melting occurred. But in some moderate scenarios, the results could be devastating to coastal cities and low lying countries like Holland and Bangladesh. In the worst scenarios, the effects could be even more widespread. One possible effect could be the disruption of the phytoplankton blooms that essentially form the base of the food chain for the oceans. Any devastating disruption of the plankton would have effects that would be felt throughout the Earth.
6. Continental snow caps would melt earlier in the year.
7. As much as 30 percent more water would flow into the Arctic from Canada and Siberia. What result this might produce isn't known.
8. With early snow melting and spring rains passing quickly, there would be consistent droughts in many areas of the Northern Hemisphere. For instance, the heartland of America would very likely see a dust bowl to dwarf the famous event of the 1930s so vividly depicted in John Steinbeck's *The Grapes of Wrath*.

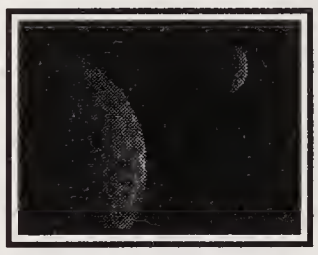
These are just some predictable effects, and they only predict a rise of 3º. This may turn out to be a conservative estimate if we continue to pollute the atmosphere with greenhouse gases at our present rates. And predictions of the effects of global warming go far beyond these gloomy images. For instance, sea levels will rise, even without the impact of ice cap melting. Just as mercury rises when it heats up, so will the water expand. Today's sea levels are about 4 inches higher than they were a hundred years ago. For instance, if sea levels were to rise by even one foot, the results could be devastating for some areas of the world. If the seas rose a foot and a half, the state of Massachusetts would lose about 10,000 acres of land.

Actually, the speculation about the effects of global warming could fill books, and nobody really has a clue as to what the whole picture could be like. We can't model weather more than even a few days in advance, and major climatic changes are just too complex and unpredictable for us to know.

The fears of global warming seem to come and go as our climate seems to warm and cool. However, there is an effect that most people fail to recognize. That effect is the slow tendency toward warming. Some people think that if there will be a disastrous warming, it will happen all of a sudden and everything will change almost overnight. The fact is, it will happen in a step-like fashion. For instance, if an area usually experienced days with temperatures

above 100º F five days a year, the likelihood is that they would begin to experience maybe twenty such days a year. If floods and hurricanes of certain magnitude happened every twenty years, they might start occurring every five years. Overall, there would be terrible years (like 1988, which set records for heat, forest fires, and other disasters), and then there would be more temperate years in which the problem seemed remote. The danger is that we have done nothing to stop the trend, and it will continue to get worse. Even if we were to stop burning fossil fuels and producing the monumental amounts of carbon today, it would probably take at least fifty years before any changes would occur. The best guess of many scientists is that we are already in the global warming and that we will have to be prepared for some unexpected and possibly cataclysmic events over the next fifty to one hundred years.

On the other hand, perhaps it's a comfort to know that the red giant Betelgeuse is near the end of its life span. This star, about 500 light years from Earth, could go supernova any time in the next few thousands or tens of thousands of years. If it did, according to Jonathan Weiner, it would most likely send such a blast of ultraviolet light and X-rays that it would strip off the ozone layer entirely, at which point the radiations from our own Sun would destroy the biosphere. O.K. That's probably not a comforting thought after all, but we have to keep in mind that we should be prepared for just about anything. My feeling, though, is that we should take care of our own problems and hope for some cooperation from Betelgeuse, stray comets and planetesimals, and whatever other cosmic forces are lurking around the galaxy.



Clouds

Exactly how clouds form, and what makes rain fall is only partly understood. Certainly Man hasn't yet harnessed his understanding of these effects well enough to control droughts. However, there are some interesting theories about how Gaia may regulate cloud cover. In *The Ages of Gaia*, James Lovelock suggests a strong link between cloud formation and Gaia regulation.

"During extensive investigations of the world oceans, M. O. Andreae has shown that marine organisms emit vast quantities of dimethyl sulfide. These emissions are particularly marked over the 'desert' areas of the open oceans far away from the continental shelves. This finding led meteorologists Robert Charlson and Stephen Warren to propose that the rapid oxidation of dimethyl sulfide in the air over the ocean could be the source of the nuclei needed for the condensation of water vapors to form clouds. The aerosol of sea salt which might be thought to nucleate cloud droplets is much less efficient than are the microdroplets of the sulfur acids. The oceans cover about two-thirds of the Earth's surface and their color is a dark blue. Anything that affected the cloud cover over the oceans could powerfully affect the climate of the Earth. In a joint paper, the four of us have reported calculations to estimate the effect that the present natural emissions of dimethyl sulfide could have; these suggest that it is comparable in magnitude with that of the carbon dioxide greenhouse, but in opposition to it."

Boast not thyself of tomorrow; for thou knowest not what a day may bring forth.
—Old Testament
Proverbs 27:1

water vapor, and a few others—to allow high wavelength radiation to penetrate, but to bounce back or block the penetration of lower wavelengths. The result is that they allow the original heat and light through, but then bounce back lower radiations (infrared, also known as heat), to cause a reverberation effect and raise the air temperature.

Today, many people believe that the greenhouse effect was responsible for keeping Earth very hot during the age of the dinosaurs. A large concentration of CO_2 in the atmosphere would have been the probable cause. This high heat promoted the environment in which the dinosaurs thrived for millions of years, but may have been an aberration compared to the Earth's normal state. As Lovelock puts it, the Earth was running a fever.

Cloud Formation

This is a control that people in drought-stricken areas wish they had. It controls the tendency of clouds to form from the amount of water vapor in the air.

Clouds can have different effects on the planet. Increasing Cloud Formation should increase rainfall. It might also block heat, especially if Cloud Albedo is high.

Rainfall

This tool controls the amount of rainfall on the planet. Obviously, this will affect the biosphere, changing the composition of the biomes. For instance, if there are large deserts on the planet, increasing rainfall should cause them to change into grasslands, forests, swamps, or jungles—depending on the ambient temperature in the region and the amount of rainfall increase. Decreasing rainfall might cause a jungle to change to a swamp or a forest to a grassland.

For more information, see the Plant Biomes chart in the Edit Window reference (Pg. 136).

Surface Albedo

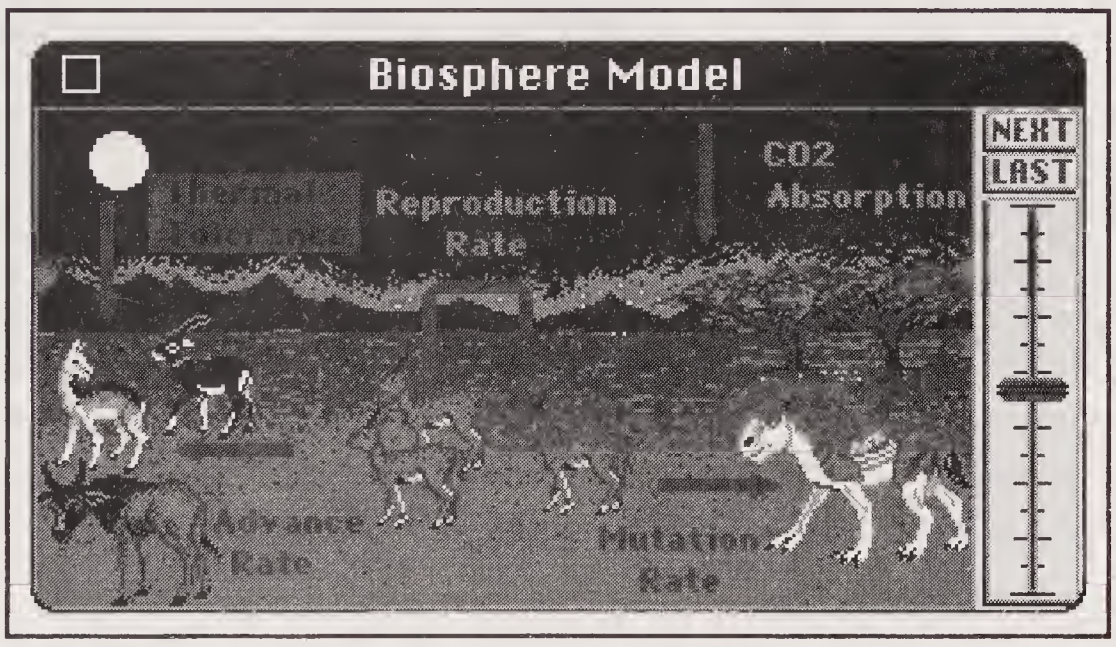
This setting controls the amount of solar radiation reflected by the surface biomes. Actually, different biomes do have different albedos. For instance, an arctic zone covered in snow and ice has a very high albedo and reflects back a lot of light and heat. In contrast, a dark green jungle has a low albedo. It absorbs a lot of heat and light. The very color green

is designed to absorb a lot of the predominantly yellow light of the Sun. It isn't an accident. The net result is that large forests tend to warm the planet while large areas of ice or desert will tend to cool it.

Air-Sea Thermal Transfer

This controls the rate at which temperature differences are resolved between the ocean and the air. Although the air temperature may change radically during a single day, and certainly during the seasons, the watery expanses of the ocean retain their heat much longer. Therefore, the water on the planet acts as a temperature regulator, slowly giving up heat when the air is cold and absorbing heat when the air is particularly warm.

If you increase the Air-Sea Thermal Transfer setting, you should see a less stable air temperature. The oceans can no longer act as a regulator. If you reduce this setting, you still prevent the oceans from performing their role as a regulator, and, again, you make the air less stable.



The Biosphere Model Control Panel

Open the Biosphere Model Control Panel by selecting Biosphere from the Models menu or by clicking on the Bio button in the Map window. You may also be able to use a keyboard shortcut.

The Biosphere Model Control Panel consists of five tools—Thermal Tolerance, Reproduction Rate, CO_2 Absorption, Advance Rate (Split Rate on IBM PC compatibles), and Mutation Rate.

Thermal Tolerance

This controls the adaptability of the living creatures on your planet to extremes of temperature. Set this higher to allow them a wider range of comfortable climates. This should make it easier for life to survive ice ages and to settle in less hospitable areas.

Reproduction Rate

This controls how quickly the creatures on your planet reproduce themselves. Setting this very high can have an adverse effect since it can cause the planet to become overcrowded. However, this can be a useful tool at times, especially when you are trying to get certain populations to increase more rapidly. Use with caution. There's a reason that rabbits breed like rabbits and most of us don't.

Do not stand in a place of danger trusting in miracles.
—Arab proverb

Lemmings reproduce so fast that they eventually overpopulate their territory. While trying to find new land, they often die in huge numbers crossing dangerous waterways.

CO_2 Absorption

This tool controls how much carbon dioxide the plants on your planet will take out of the atmosphere. This is messing with basic chemistry, but it can be very effective in controlling how much carbon dioxide is in the atmosphere, and, therefore, the temperature.

Advance Rate (Split Rate)

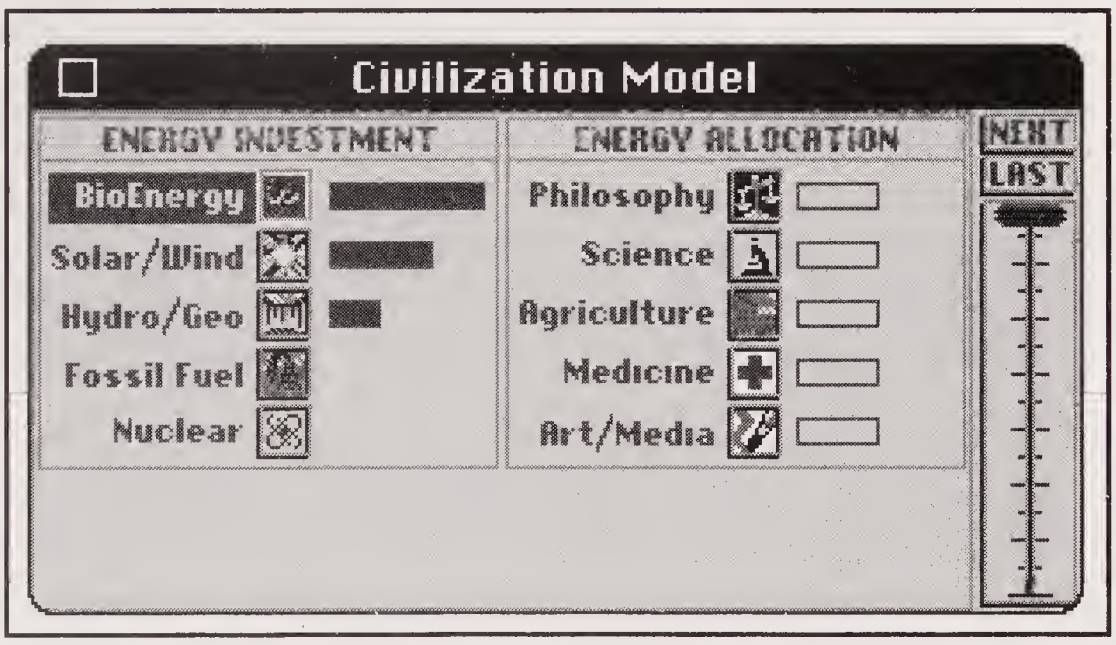
Use the Advance Rate to help your life forms reach more advanced states of evolution more quickly. Each life form has

16 different stages of its evolution, eventually leading to sentience in the case of the multicellular creatures. A high Advance Rate speeds them through the evolutionary process and propels them toward intelligence quicker.

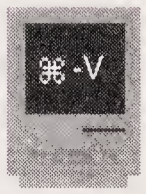
Mutation Rate

Increasing the Mutation Rate increases the chances of the life forms in SimEarth skipping to higher forms of evolution.

Mutations are the way that life experiments on itself. Mutations, though most often failures, are responsible for the ability of life to adapt to new circumstances and to try different strategies of life. If a mutation provides an advantage to a life form, that mutation tends to be favored and more creatures will be born with that mutation. For instance, in a green world, it may be an advantage to be a green frog. If most frogs are brown and one is born green, that frog may survive longer and reproduce more. Soon there will be a lot of green frogs, and the brown frogs might die out altogether over time.



The Civilization Model Control Panel



Open the Civilization Model Control Panel by selecting Civilization from the Models menu or by clicking on the Civ button in the Map window. You may also be able to use a keyboard shortcut.

The Civilization Model Control Panel consists of two main sections—Energy Investments and Energy Allocations. In the Energy Investments section, you

can choose to invest your civilization's energies toward each of five different energy sources—BioEnergy, Solar/Wind, Hydro/Geo, Fossil Fuel, and Nuclear. In the Energy Allocation section, you can take the energy generated by your people and determine how it gets used in each of five categories—Philosophy, Science, Agriculture, Medicine, and Arts/Media.

The Energy Investments Section

Bioenergy is the burning of wood, the use of animals, farming, and manual labor by the citizens of the civilization.

Solar/Wind power is used in various ways, including using the sun to dry food and clothing, windmills, sailboats, solar heating, and more modern methods like photo-voltaic cells, satellite collectors, and more.

Hydro/Geo is the use of water and earth power. For instance, water wheels and dams are long-standing methods of using water for power. In addition, there are steam power, hydroelectric generation, geothermal, and a host of modern schemes to use water for power, including such intriguing experimental solutions as OTEC (Ocean Thermal Energy Conversion), which uses the difference in temperature between layers of the ocean to evaporate then condense a special fluid and drive a turbine.

Fossil Fuels are oil, coal, and gas created by the decay of animals and plants that died millions of years ago. We burn fossil fuels in enormous quantities in our industry, our automobiles, and, to a lesser extent, in our homes. Indirectly we consume fossil fuels in our food since much of today's fertilizer is made from oil. Fossil fuels are non-renewable, meaning that it took millions of years to create what there is now. When we run out, we won't be able to wait for nature to create more.

Nuclear power is derived from the energy released during the decay of radioactive substances. By placing radioactive materials in close proximity with each other, under controlled conditions, a lot of

The Fuel Dilemma

Using fossil and nuclear fuels in SimEarth can produce some unpleasant results. While it does increase energy output, it also has some side-effects. For instance, as these non-renewable fuels begin to run out, people will start to fight over them. World wars will break out, and if nuclear use is up, the war can be a deadly nuclear war. One result of an all-out nuclear war is nuclear winter, which can wipe out most life on the planet. Another result is toxic, irradiated sections of the planet that are unfit for life for thousands, or even millions of years.

Possible results of using fossil fuels:

- Depletion of the scarce resource.
- Local pollution (oil spills and toxic emissions).
- Rising carbon dioxide and greenhouse warming.
- World war.

Possible results of using nuclear fuels:

- Depletion of the scarce resource.
- Nuclear war.
- Radioactive areas.
- Nuclear winter.

energy is released which we can harness. However, there are always byproducts of the fission process, and proper and safe disposal of these byproducts is a serious problem. Since they can remain toxic for thousands or hundreds of thousands of years, our technology is not able to cope effectively with their storage or disposal. Also, some byproducts, like plutonium, can be used to create atomic bombs. It is a matter of world security to make sure these substances don't fall into the wrong hands.

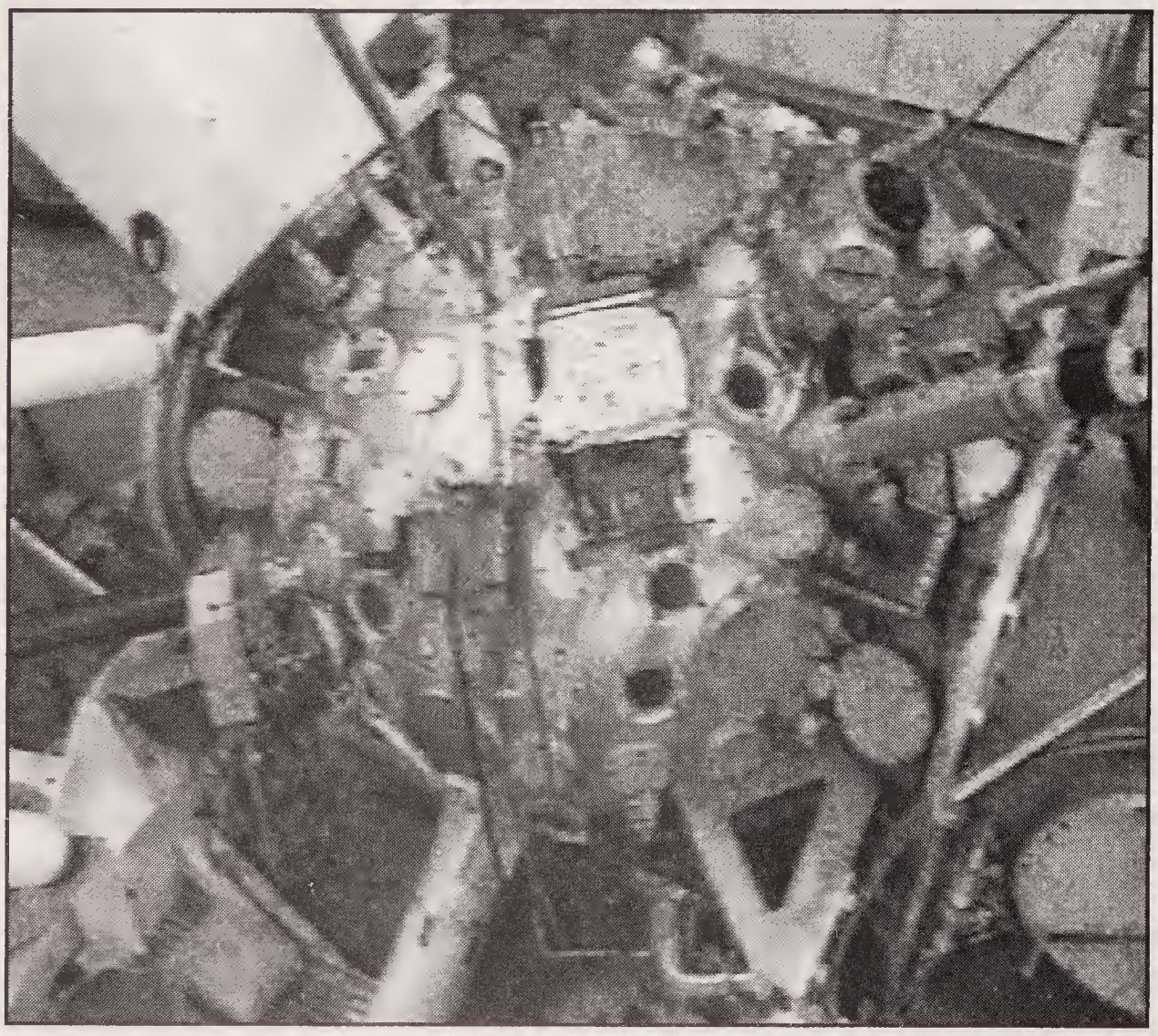
The Energy Allocation Section

Philosophy creates a more thoughtful race; one that does not rush into war. Therefore, when the Philosophy allocation is high there will be fewer wars and they will be less violent.

Science is the key to technological advancement, and so is necessary for your civilization to get past its

Energy Sources

Most of the energy we use today is from non-renewable resources. The main ones are oil, coal, and natural gas, and it is no secret that we are using them up fast. Oil, in particular, isn't going to last much longer unless we find new sources of it. As we are learning, our dependence on oil and fossil fuels has all kinds of adverse effects on our world and ourselves, but we persist.

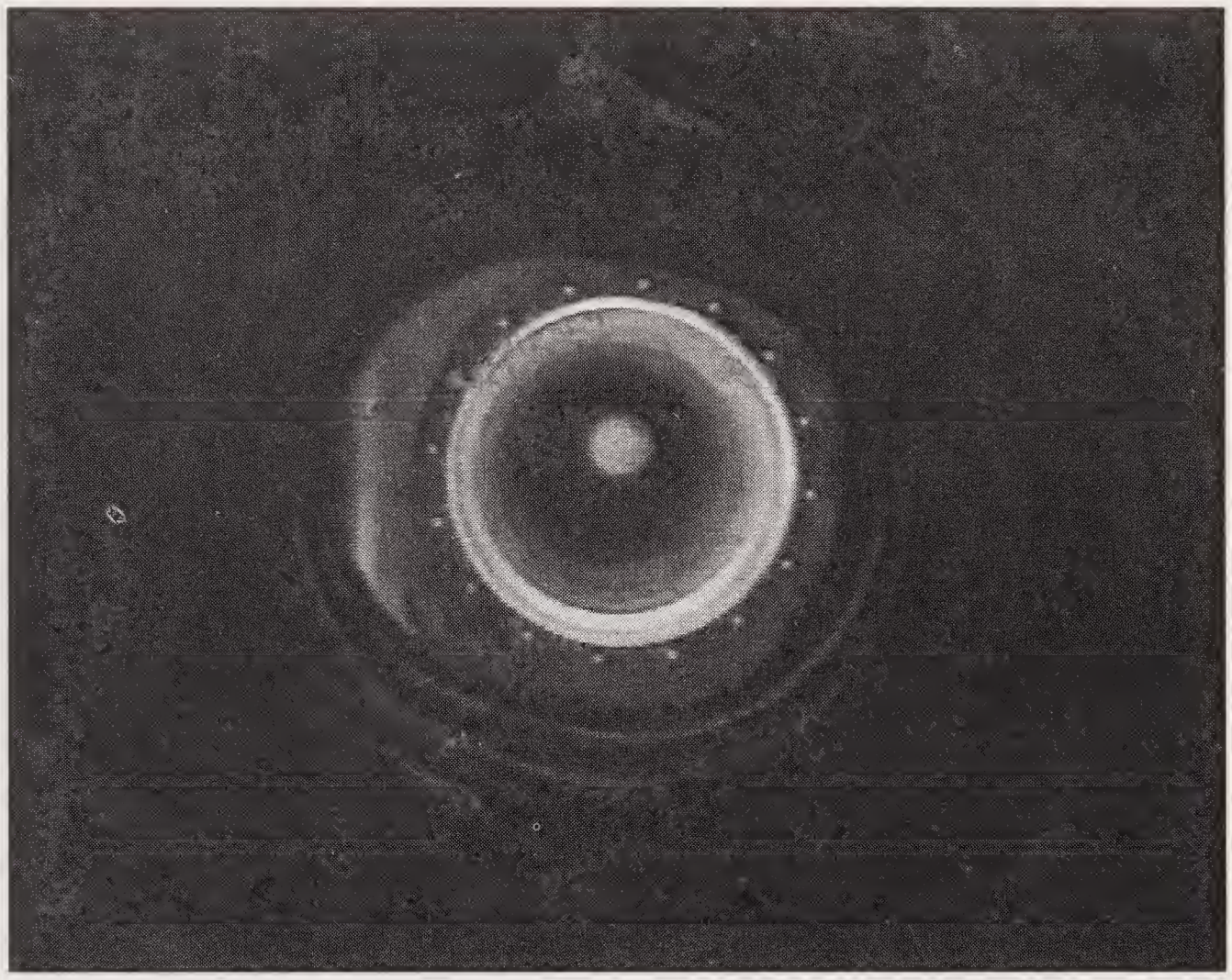


Nuclear fusion gadget at Lawrence Livermore Labs.

Once we thought nuclear power would save us, but we've managed to supply very little of our energy with nuclear power stations, and the dangers of leaking radiation and the still unsolved problem of nuclear waste storage all make the fission road a bumpy one.

There are always the high-tech hopes. People are working hard to create fusion reactors—potentially much safer than the fission version, and cleaner. However, nobody has yet succeeded, and even if they do, the chances are that the hardware needed to build

fusion power stations won't be practical in our modern economy. If the dream of "cold fusion" becomes a reality, we will certainly be fortunate, but few scientists are holding their breaths.



Down the fusion "gunsight."

Of course one renewable energy source has been used almost from the dawn of man. That is biomass. Even today, probably 80% of the world still uses wood as its principal fuel, and a great deal more is used to build houses and to make products like the paper this book was printed on. Unfortunately, this reliance on wood is contributing both to the deforestation of our non-renewable tropical rainforests, and to the global warming problem through the release of more carbon into the air.

Geothermal energy plant in Iceland.

The other sources of energy include hydro power from falling water which generates perhaps 25% of the world's electricity. This is a resource that has been widely utilized, but much potential still exists.

Solar power may one day be our main source of energy, especially if we could find a way to harness the nearly immeasurable energy that simply dissipates into space. Today, despite some limited uses, man harnesses very little of the solar energy that reaches the Earth, to say nothing of the rest.

Geothermal power taps directly into the Earth, which grows about one degree hotter for each meter you go

down. In some places, the heat of the Earth is very close to the surface. Whether it is a good idea to try to use that energy depends on circumstances. In Iceland, it is an ideal source of clean, abundant power and heat. In Yellowstone National Park, it wouldn't be a good idea to ruin such a natural resource or to endanger the water table.

Windmills are nothing all that new, but today's wind generators are a great deal more complex and sophisticated than the early medieval windmills of Don Quixote. How much power the wind may provide is uncertain, but in some ideal places, windmill farms can generate a considerable amount of energy.

Steam from an Icelandic geothermal power station.

A windmill farm.

The forces at work in the oceans of our world are immense. Anyone who has surfed or taken a ride on a big wave has felt that power first-hand. Power from the sea is only a fairly new technology, but one that may have some promise. If people can find ways to turn the power of waves, tides, or currents into usable energy, they will have discovered another huge source. In addition, there are some ways to use the temperature differentials at different levels of the ocean to generate power. Though we may never even scratch the proverbial surface of the ocean's energy potential, it is one to consider.

Yellowstone.

Food Distribution

The world is capable of producing food for the billions of people who inhabit it. In fact, there is enough food to go around. The problem is that it isn't going around. It's going into the mouths of a few while many others live on subsistence or starvation diets. The problem is not one of supply so much as it is one of distribution with a dash of corruption and greed thrown in. There are countries where the average population is very under-nourished, but alongside the starving are rich, gluttonous people who exploit their people. This is true in many countries including Kenya, Brazil, Mexico, and Iraq (just to mention a few). In fact, the cats of most American and European families eat better than many people in poor countries.

In other countries like China and Sri Lanka, the overall population does not live on the prodigal diets that most Americans and Europeans are used to, but almost nobody starves. It's that distribution thing again. The food is equitably distributed to the people, not hoarded in the hands (or mouths) of a few.

Certainly some countries have devoted their resources to cash crops and should grow more of their own food, but the problem is also one of equity and distribution. There's really no excuse for people to starve. The world is rich and generous in its production of food. But when Americans waste fully a quarter of their food to spoilage and eat on average 40 percent above the number of calories needed for well-being, it's hard to accept that so many people live on diets that can barely sustain them.

Cash Crops

Much of the world is hungry. It is easy to forget how many people are hungry in the world, but the number of people who die of starvation each year is equal to about the number of deaths that would result from 300 jumbo jet crashes a day—with no survivors and half the passengers being children. We see it on the news every time a big plane crashes, but nameless millions die each year with little or no attention.

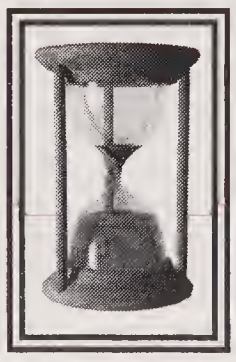
While people starve, our land use practices are causing erosion and desertification at a fast pace. We basically destroy millions of acres each year through neglect, ignorance, and greed.

Meanwhile, in many of the places most hard hit by both these crises, the local resources are being used to produce materials to feed the enormous demands of the richer nations. These are the cash crops, the crops that help make money, but don't feed a nation or a world. Some of the best known cash crops are coffee, sugar, and cocoa. These crops are grown expressly for export, and yet their real value diminishes year by year. For instance, in 1975 one ton of sugar could buy four barrels of oil while in 1983 that ton only bought one. The end result is that countries that have relied on cash crops are suffering from diminishing returns. It is the tragic irony of this situation that many countries may have record cash crops while suffering terrible famines. This has been more than adequately demonstrated in the Sahel region of Africa.

In the Sahel, agricultural resources were traditionally diverted to cash crops for export—notably cotton and peanuts. Meanwhile, nomadic herders were forced out of their traditional areas and forced into land too poor to support their own agriculture. The overall results have included the loss of marginal and poor land and the degradation of the better land. Meanwhile, when severe droughts have hit, the combination of the emphasis on cash crops and the destruction of land has caused widespread famine as the world witnessed in the early 1970s.

Another sad example is the clearing of forest land in South America to export wood to Japan and to raise beef for the voracious American market. These cash crops are instrumental in destroying one of the most important natural resources of the planet. At the same time, in the case of beef, it is the least efficient food source we have. The quantities of water and other resources it takes to raise beef cattle are enormous compared to the quantities required to produce grains and other food crops. There seems to be enough evidence just from a health perspective to justify a cut-back in beef and meat consumption in affluent societies, but with the added knowledge of its wastefulness and its potential harm to the tropical rainforests, it seems almost mandatory for people to reconsider their eating habits.

Other answers lie generally in better policies, both locally and internationally, and more attention paid to agricultural reforms. Most developing countries have focused their attention on urbanization and industrialization, and too little on efficient food production and sensible cash crop policies. Though these problems are largely local in origin, they must be addressed as global issues. The terrible imbalance between the affluent North and the dirt poor South is potentially unstable, immoral, and unnecessary. However, we all have to recognize the problem and form policies that export benefits to other countries and share our technology and wealth to aid them in achieving better conditions. At the same time, we must be conscious that we are resented all over the world for our wasteful use of resources. Since Americans use perhaps 30 percent of the world's resources for less than 6 percent of its population, it's no wonder Americans aren't universally loved and respected.



OVERPOPULATION

Ten thousand years ago, there were about 5 million people on the planet. By the 1830s the population of the Earth was about one billion. By the 1930s it was about two billion. The population had doubled in one hundred years. Only 45 years later, it had doubled again, and today our world population is closing in on 6 billion people. Scientists now estimate a population of 8 billion by the year 2020. There are serious questions about our capacity to sustain populations that large. But what can we do?

All life is sacred, and certainly human life no less than any other. And yet we must consider the quality of life, too. With too many people on the planet, it will

Crowded streets in Bangladesh.

eventually reach a point where we can no longer sustain life at a reasonable level. Have we already reached that point? Perhaps. Or, if resources were more evenly distributed, perhaps not. But one thing is certain. We can't expand our population forever.

Even those who follow a doctrine of "be fruitful and multiply" may have to accept the fact that they have succeeded. Now may be the time to reassess the commandment. For instance, if you work for a farmer and he tells you, "Go plow the field," you plow the field, and when you're done, you stop. Then he might say, "Go plant the seeds." Again, you would plant the seeds as appropriate, then stop. Every backyard gardener knows that if you plant too many seeds and don't thin them, the resulting plants are stunted and overcrowded. Why is it that something so obvious to us as that is ignored when it comes to people? I would say that we have multiplied like fruit flies and should start looking at other ways to use our energies.

Has anybody has come up with a solution to the problem of overpopulation? The Chinese government, by decree, has managed to limit the growth of the population in their country by allowing families only one child. This is not always a popular law, but it has been effective, and if population had been allowed to grow without any controls in China, millions might already have starved. If we don't want government telling us how many babies to have, how else will we do it? Certainly education and world awareness must be exported where it is most needed. Also, we must help the developing countries to have access to adequate food; clean, disease-free water; and medical treatment to lower infant and child mortality. For more about this, see the section on Deforestation.

In the end, we may not have much choice. We have set so many events in motion that our population may be reduced without our consent or volition. The world may simply change due to our actions and become less and less inhabitable. Certainly Gaia regulation will be the rule and we won't be able to break those rules forever. If we create an intolerable environment, we will perish and life will readjust without us.

Kings have long arms, but misfortune longer; let none think themselves out of reach.
—Benjamin Franklin

current state of development. All other factors being equal, a civilization devoted to Science at the expense of other factors like Philosophy, Medicine and Art/Media will probably not be stable. The exception occurs when Agriculture is given the highest priority because then the population replenishes faster than wars and plagues can destroy them.

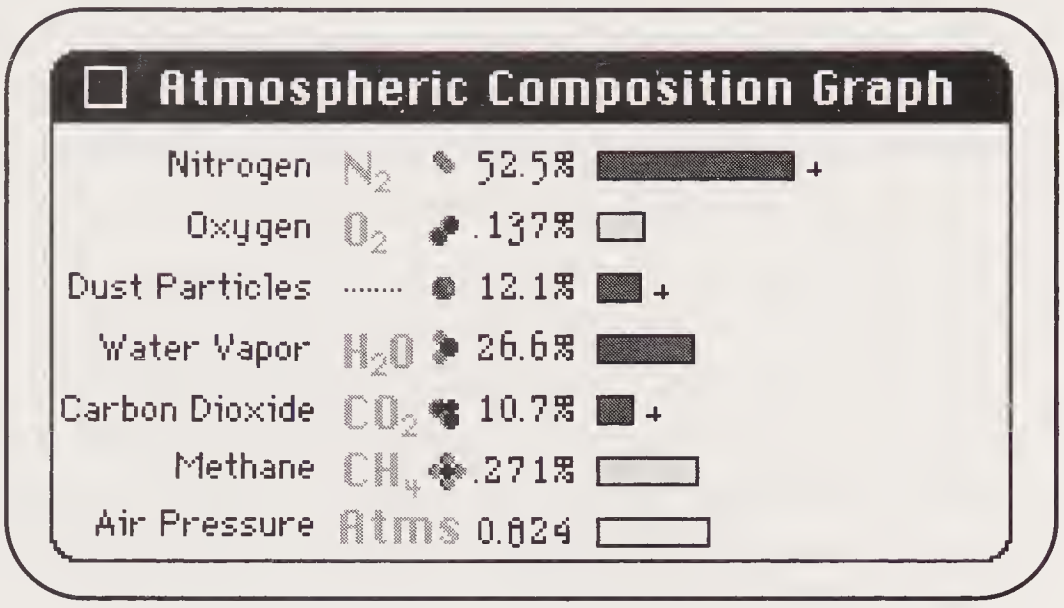
Agriculture is probably the most important use of energy for an emerging civilization. Without food, they can't expand. With plenty of food, their numbers increase incrementally—even if conditions are otherwise miserable, there are numerous wars, and plagues are epidemic. Early in a civilization, food availability seems to overcome all obstacles. At least this is true in SimEarth.

Medicine is important in preventing and curing plagues. Plagues can do a lot of damage very quickly, wiping out whole cities and even whole regions. However, as noted, with high settings in Agriculture, even plagues can be ignored. However, in the later part of the Technology time scale, when population has become incredibly dense, it is a good idea to turn up the Medicine to avoid massive, spreading epidemics.

Art/Media is the setting for the finer things in life. Though it doesn't directly influence their productivity, turning up Art/Media will produce a happier world, one that's more in touch with their lives and much more personally fulfilled. But remember, wherever you apply your energy, you're taking it away from something else. As a friend of mine used to say, "Lunch is not free." So sometimes lunch has be a pterodactyl sandwich instead of super deluxe mammoth burgers. Or, to put it another way, your people may pay for their better life quality by not advancing as quickly, or by taking energy away from some other critical area.

GRAPH WINDOWS

There are four main graph windows (plus one special graph for DaisyWorld). These are the Atmospheric Composition, Biome Ratio, Life Class Ratio, and Technology Ratio.



The Atmospheric Composition Graph

Open the Atmospheric Composition graph by double-clicking the Air Temperature icon in the Map window or by selecting Air Sample from the Graphs menu.

The composition of gases and dust in the atmosphere is critical to the health of the planet. Without the delicate balance of our atmosphere, we would not be able to live, and Gaia would be another dead world like Mars and Venus.

What distinguishes our atmosphere from those other atmospheres is its very improbability. Only an active force could create such a volatile and unnatural mixture of gases. Left to natural chemical processes, our atmosphere would eventually devolve to an inert mixture of CO_2 and other gases in what is called an "abiological steady state." This is the kind of atmosphere found on planets like Mars and Venus where all the chemicals have found their sort of bottom line equilibrium. However, the very existence of life pollutes the gases surrounding our planet and, in doing so, maintains the conditions of life. Put another way, our planetary atmosphere is a dynamic component of a system that promotes and maintains life. In a sense, it is part of life since it is only able to exist in its unstable state because of its symbiosis with life.

The Atmospheric Composition Graph shows the levels of six important atmospheric elements plus air pressure. The six elements are nitrogen, oxygen, dust particles, water vapor, carbon dioxide, and methane.

Nitrogen comprises 78.09% of the Earth's atmosphere. Though it plays no role in our respiration and is therefore inert, it probably helps maintain enough atmospheric pressure to maintain the atmosphere at a life-supporting level. In addition, nitrogen is essential to the growth of plants, and there is an abundant supply, though it must be processed by specialized bacteria to become usable.

Oxygen comprises 20.95% of the atmosphere. Highly reactive, it is oxygen that most Earthly life uses to fuel its activities. It is oxygen that fuels fires when we burn wood. In the same way, our bodies burn oxygen in a controlled way. As James Lovelock has pointed out, the levels of oxygen in the atmosphere must be kept within very narrow limits (between about 15% to 25%) or life would simply be impossible.

Dust is always in the air. Most dust settles out of the air quickly, but some particles called aerosols may float in the atmosphere for years. Dust is often sent into the air by volcanic eruptions. Other possible sources include meteor strikes and nuclear explosions. Following cataclysmic events, dust can block sunlight and have a severe effect on weather, and, in extreme conditions, on life itself.

Water Vapor is always in the air, in varying proportions. Water vapor is necessary for cloud formation and for rain. Above a desert, there is very little water vapor in the air. In contrast, above a tropical rainforest, the vapor is so thick that it can be seen as a mist rising above the trees.

Carbon Dioxide in today's atmosphere measures about 350 parts per million (ppm), but it is rising. In the early 1700s, the normal level was about 280 ppm (as measured from ice cores which trap the air and can be analyzed). In the 1950s it was only about 315 ppm. The significance of this rise is monumental since carbon dioxide is a powerful greenhouse gas. As carbon dioxide levels rise, the prbability of a severe global warming looks more and more likely.

Carbon is kept out of the air by many mechanisms. Some is deposited in the shells of dead sea creatures. Some has been buried in the earth as

coal and oil. A lot of carbon is trapped in trees. When we burn coal, oil, and trees, when we process lime to make cement, in fact when we breathe, we release the carbon into the atmosphere. Our breathing can be considered more a recycling job and seems to fit into the scheme of things pretty well, but our wholesale release of carbon through industrial activities is adding tons of carbon to the air every year. In fact, between 1860 and 1960 almost 80 billion tons of carbon was added to our atmosphere from fossil fuel burning alone, and the rate is only increasing!

Methane is another greenhouse gas, twenty times as powerful as carbon dioxide, although it doesn't last in the atmosphere as long. Still, methane levels are also rising. Currently methane levels are rising at about one percent per year. Current levels are about 1.7 ppm. There are many natural sources of methane, but several under human control include our burning of petroleum and mining of natural gas, cows, clear cutting forests, and rice paddies. Cows belch about twice a minute and contribute several pounds of methane each week. Termites also release methane, so when forests are cleared to make cow pastures, methane increases in two ways. And rice plants act as hollow tubes that funnel natural methane created in the anaerobic muck of the paddy and release it into the air.

Air Pressure is measured in SimEarth on the Atmospheric Composition Graph. Basically, at sea level, the atmospheric pressure is one. In general, atmospheric pressure won't change much in the Earth-like scenarios. However, in the Mars and Venus experiments, atmospheric pressure can be important. Basically, without enough pressure, sufficient heat may not be retained and important gases might be lost to space. Our atmospheric pressure on Earth seems to suit us (and Gaia) rather well.

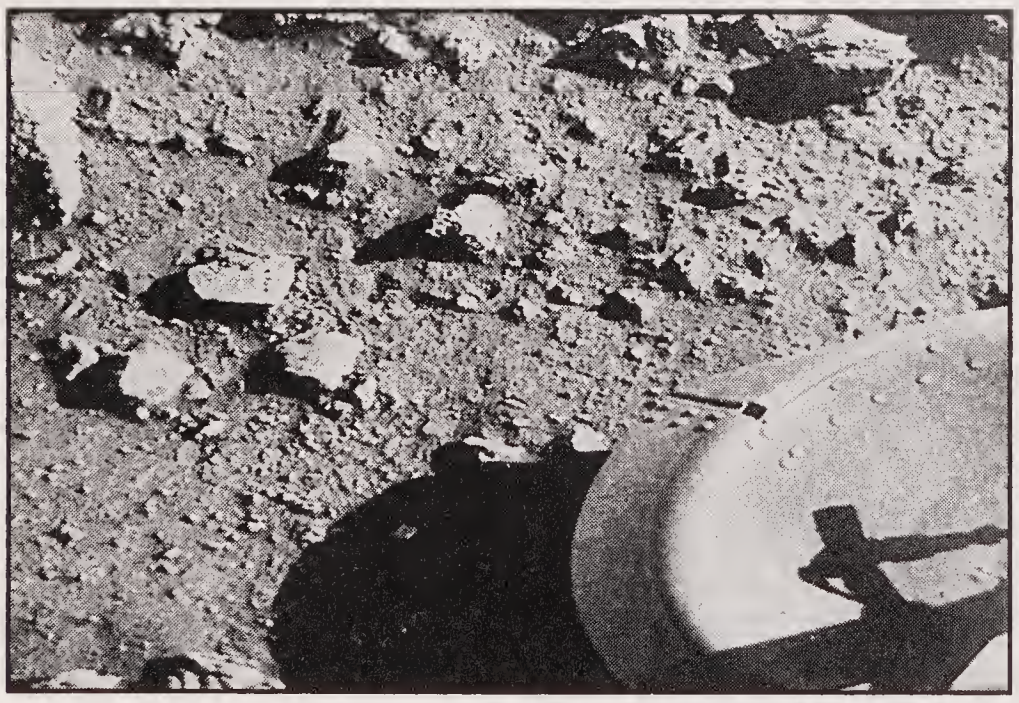
Reading the Atmospheric Composition graph is easy. The color or, in the absence of color, the shade of each bar gives you an instant clue about its relative abundance in the atmosphere. A plus or minus symbol at the end of the bar is present if the value is currently changing. Finally, an exact percentage of its composition is given in numbers.

The Atmosphere and the Presence of Life

James Lovelock has been one of the leading atmospheric scientists of the past few decades. Using his knowledge of our atmosphere and his understanding of life and its processes, Dr. Lovelock was able to assert that Mars was lifeless before any missions reached the planet. Here's some of what he has to say on the subject in *The Ages of Gaia*.

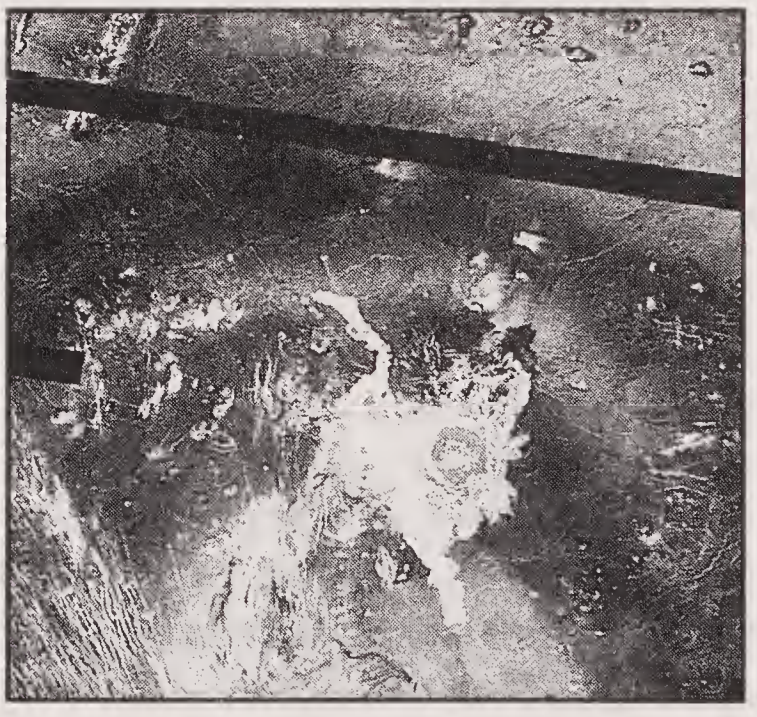
> The least complex and most accessible part of a planet is its atmosphere. Long before the Viking spacecraft landed on Mars, or the Russian Venera landed on Venus, we knew the chemical compositions of their atmospheres. In the middle 1960s, telescopes tuned to the infrared radiation reflected by the molecules of atmospheric gases were used to view Mars and Venus. These observations revealed the identity and proportion of the gases with fair accuracy. Mars and Venus both had atmospheres close to the chemical equilibrium state; if you took a volume of air from either of those planets, heated it to incandescence in the presence of a representative sample of rocks from the surface, and then allowed it to cool slowly, there would be little or no change in the composition after the experiment. The Earth, by contrast, has an atmosphere dominated by nitrogen and oxygen. A mere trace of carbon dioxide is present, far below the expectation of planetary chemistry. There are unstable gases such as nitrous oxide, and gases such as methane that react readily with the abundant oxygen. If the same heating-and-cooling experiment were tried with a sample of the air that you are now breathing, it would be changed. It would become like the atmospheres of Mars and Venus: carbon dioxide dominant, oxygen and nitrogen greatly diminished, and gases such as nitrous oxide and methane absent.

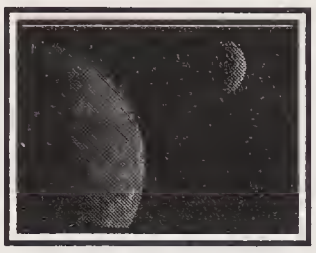
First Photos



The first photo from Mars—Viking 1 in 1976.

One of the first Magellan photos from Venus. An impact crater in the Lavinia Region taken in 1990.





Atmospheric Layers

Our atmosphere is composed of four main sections—the Troposphere, the Stratosphere, the Mesosphere, and the Thermosphere. From our viewpoint, the Troposphere is "home." All the weather we experience is in this relatively small layer a little more than ten kilometers high. Tropos comes from the Greek word meaning "turning" and that is because the air in the Troposphere is in constant movement—a phenomenon we're all very familiar with.

Though it is a distinct layer which mixes very little with the Troposphere, the Stratosphere is remarkably important to us down below. It is in the stratosphere that the ozone layer protects us from much of the harmful ultraviolet radiation from our Sun. The stratosphere extends up above 50 km.

From our perspective, the remaining two layers of the atmosphere are practically outer space. Thin and too high up to reach by anything but an unmanned balloon or a rocket, these layers form the final barrier between the fragile envelope that sustains us and the cold forbidding realm of space.

Earth's atmosphere as seen from orbit.

The Ozone Hole

One of the best publicized ecological disasters we have discovered is the hole in the ozone layer above the Antarctic. Researchers became suspicious of the hole in the early 1980s, and by 1985 they were convinced that it was a serious problem, that it was growing, and that its origins were man-made. Early satellite pictures had ignored the hole because their programs had been created to ignore unlikely fluctuations that would ordinarily have been caused by bad data translations. Once this error was discovered, we got a good look at the growing ozone hole.

The main culprit is the chlorofluorocarbon or CFC which breaks down in the upper stratosphere. The free chlorine then attacks the ozone in a chemical reaction, forming among other things, hydrochloric acid. Even though world reaction was remarkably quick in response to the evidence of the ozone hole, and in many countries CFCs were banned or their use cut way

A plankton bloom 320 km long.

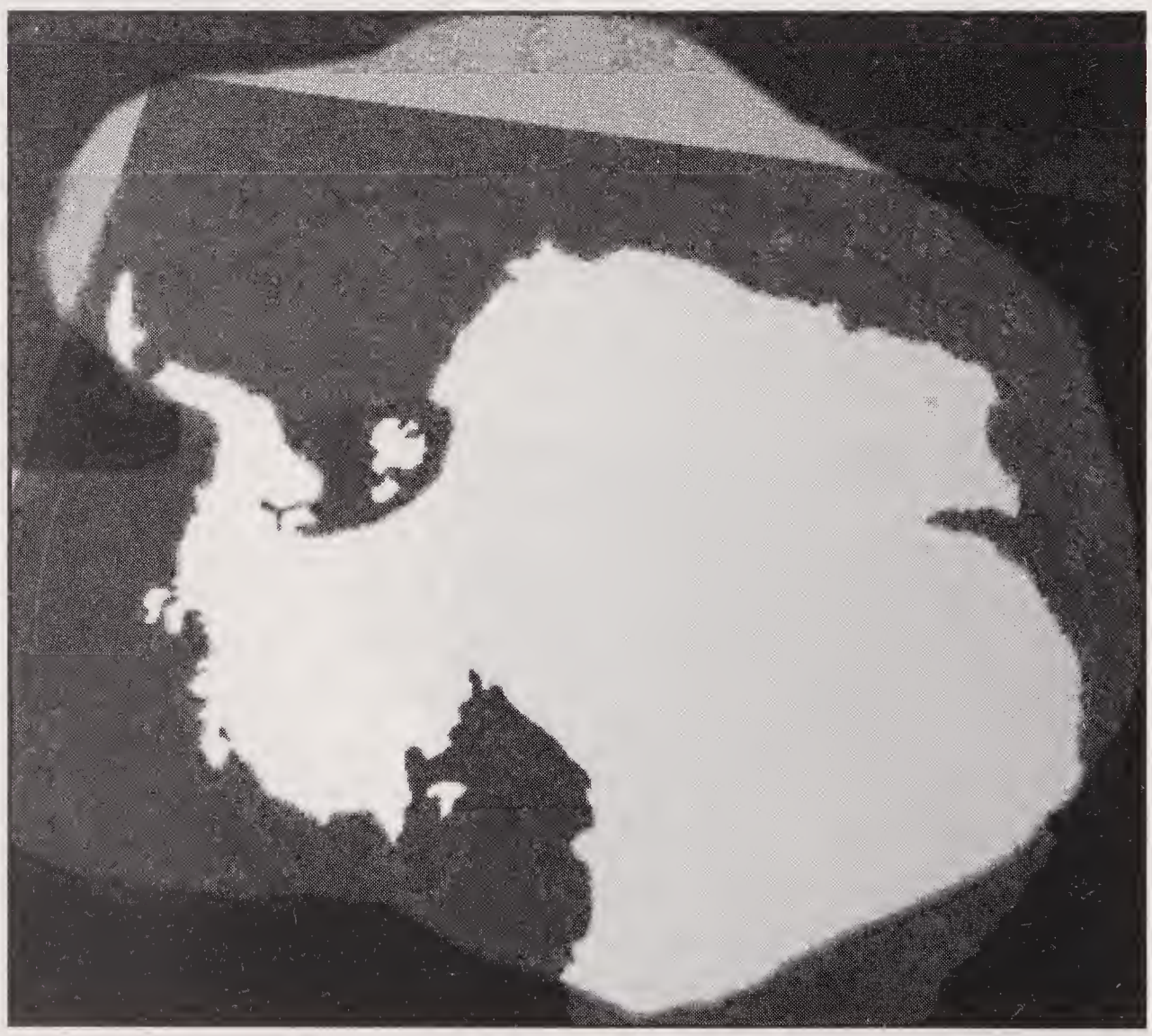
back, the bad news is that CFCs are still used in many countries, and even in those countries that cut back, they continue to enter the atmosphere in alarming quantities.

The most immediate effects of a thinning of the ozone layer are higher incidences of skin cancer among humans, but long range effects could be much more devastating, including real threats to our food chain through damage to plants and even to the plankton blooms that form the basis for the ocean's food chain. These plankton are mentioned several times in this book. That's because if they are threatened, we are all threatened. It's good to keep that in mind when you get complacent about the environment.

In *The Next Hundred Years*, Jonathan Weiner has printed a paragraph that pretty adequately expresses my own frustrations:

> "The world's foot-dragging brings many scientists to despair. It exasperates Sherwood Rowland, who sounded the first alarm back in the 1970s. 'After all,' Rowland has said, 'what's the use of having developed a science well enough to make predictions, if in the end all we're willing to do is stand around and wait for them to come true?'"

Evidence now shows that the ozone layer as a whole eroded by about 2.5% between 1978 and 1985. The newest reports say the hole is growing even faster than anticipated.

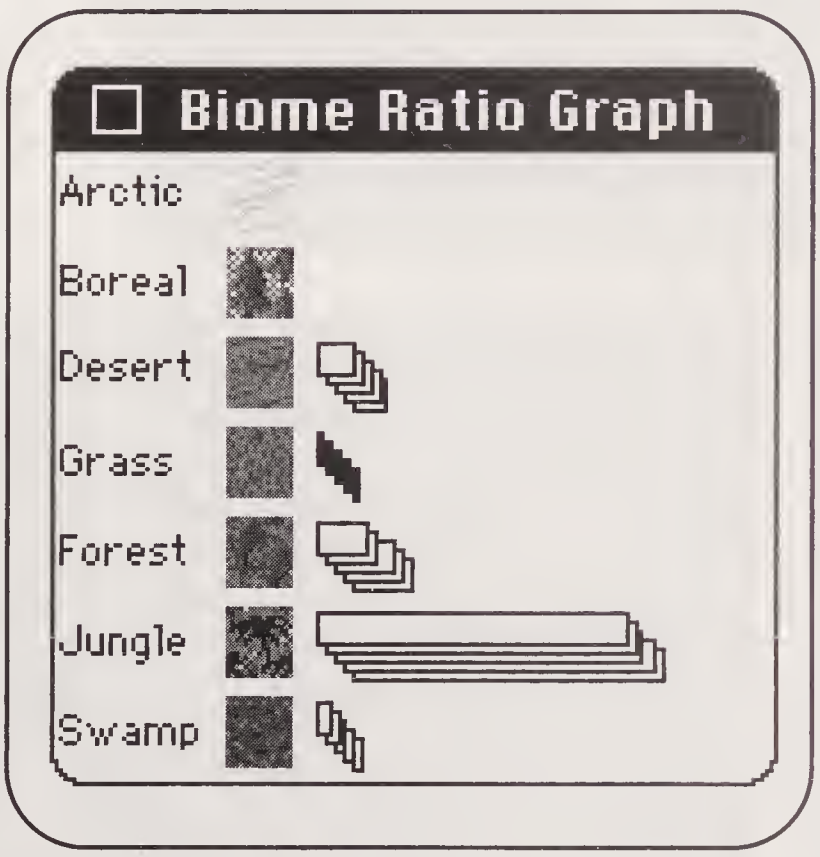


An artist's conception of the Antarctic ozone hole circa 1984.

The Biome Ratio Graph

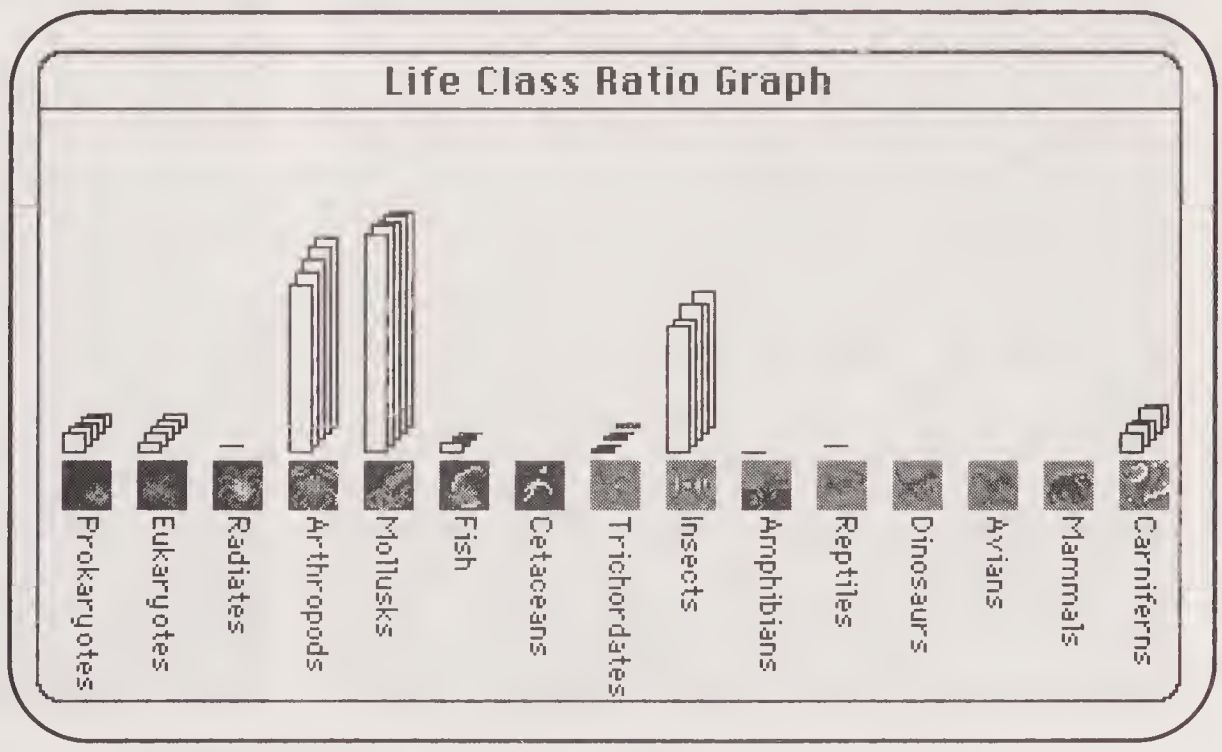
Fear not, provided you fear;
but if you fear not, then fear.
—Blaise Pascal

Open the Biome Ratio Graph by selecting Biomes from the Graphs menu or by double-clicking the Biomes icon on the Map window. This graph shows the relative distribution of biomes on the planet. You'll notice that each biome is represented by a series of five bars. The higher the bar, the greater the amount of that biome. The front bar represents the most recent sample. The bars behind it represent previous samples. By reading from front to back, you can tell whether a specific biome is increasing or failing.

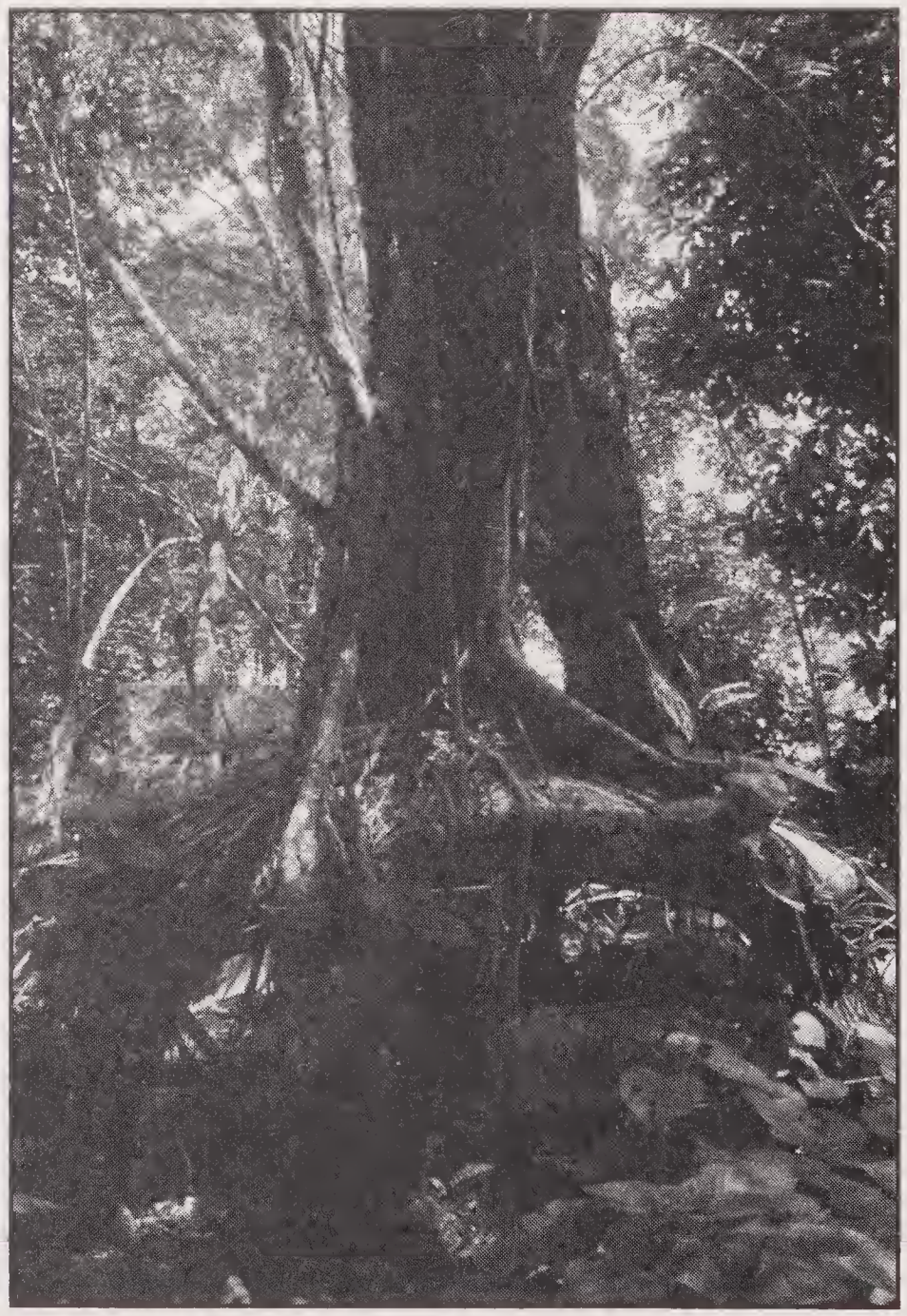


The Life Class Ratio Graph

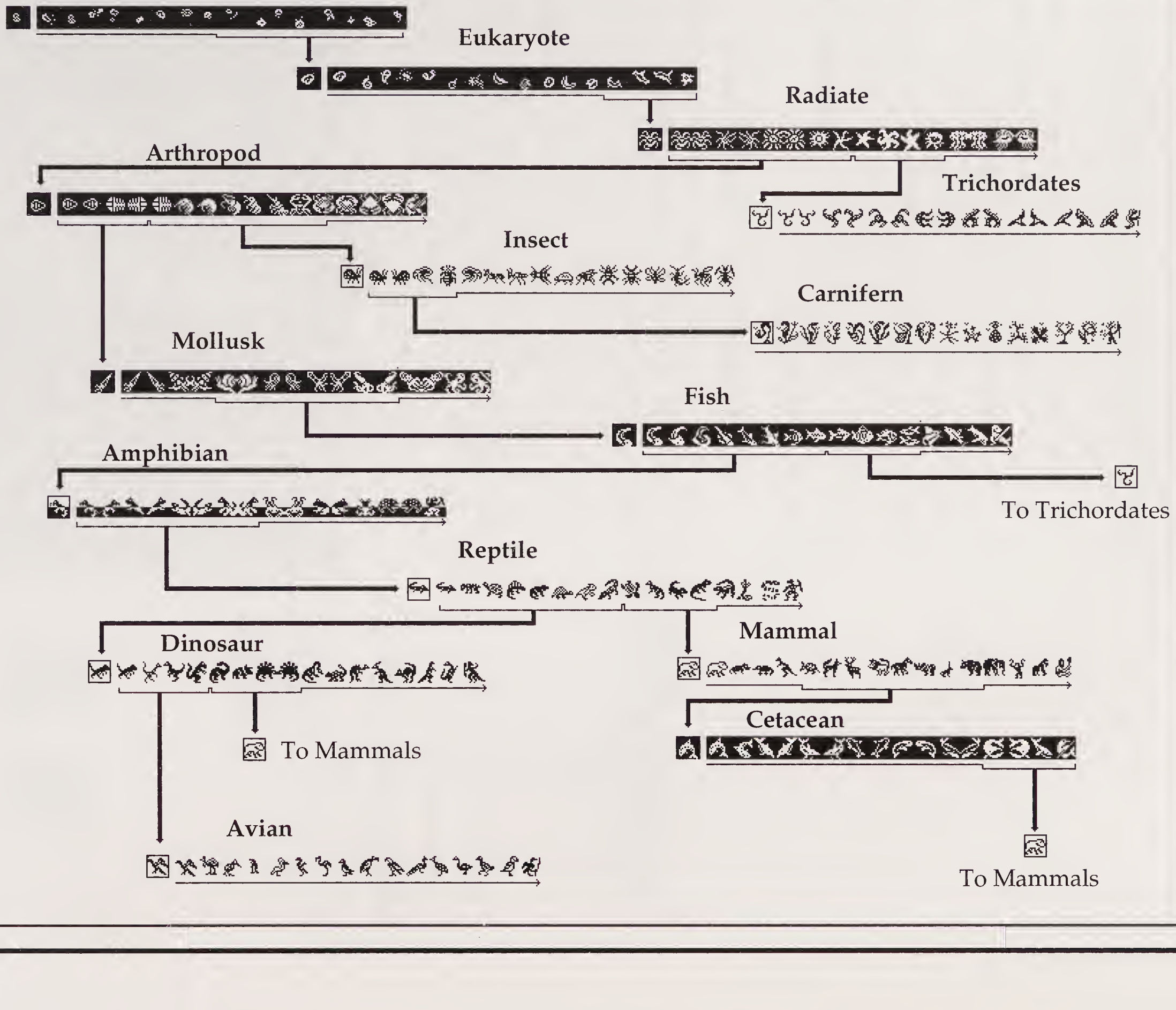
Open the Life Class Ratio Graph by selecting Life-Forms from the Graphs menu or by double-clicking the Life icon on the Map window. This graph shows the relative distribution of life classes on the planet. You'll notice that each life class is represented by a series of five bars. The higher the bar, the greater the number of that life class inhabiting the



SCENES FROM THE RAINFORESTS



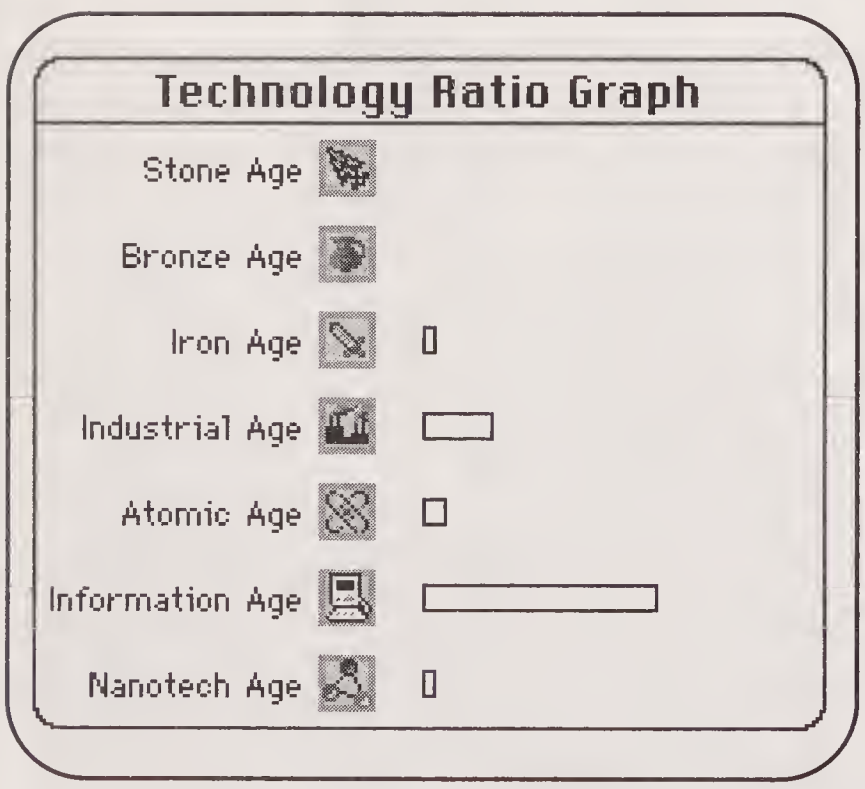
SimLife Evolution Chart



planet (and generally the more viable that life class). The front bar represents the most recent sample. The bars behind it represent previous samples. By reading from front to back, you can tell whether a specific life class is increasing or falling on hard times.

It is possible to have some life forms while others have died out. However, just because a life form doesn't have a bar on the Life Class Ratio graph, it doesn't always mean it's extinct. However, it does mean that there aren't sufficient numbers to register. On the Macintosh, the icon for the specific life class will disappear if there are no examples left.

In SimEarth, a life class that becomes extinct can evolve again in time. If conditions are right, creatures who have died off may reappear. This is probably not likely in the real world, however.



The Technology Ratio Graph

Open the Technology Ratio graph by selecting Technology from the Graphs menu or by double-clicking the Civ icon on the Map window. The Technology Ratio graph simply shows, in bar form, the relative abundance of each level of civilization on the planet at any given time. As a new technology spreads, you'll see its bar get longer and the bars of earlier technologies grow shorter until eventually they disappear.

It is possible to have Stone Age civilizations existing on the same planet with Nanotech civilization. However, as civilizations become more advanced, they spread out faster and reach all areas of the globe. Therefore, the really primitive civilizations will be engulfed by Atomic Age and Info Age people with their planes and expanding populations.

Nanotech cities don't travel, so they don't spread quickly. It takes a long, long time to develop a planet with predominantly Nanotech cities. However, it isn't necessary to do so to reach Exodus.

The Gaia Window

The Gaia window displays an anthropomorphic view of Gaia as an entity. She reacts to the things you do in the simulation and gives some limited feedback during the game. However,

you may want to ignore her messages if you already know what you're doing. If she asks, "What are you doing?" (which she does a lot), just be sure you know the answer. It won't do any good to argue with her, though.

MENUS

Apple Menu

About SimEarth

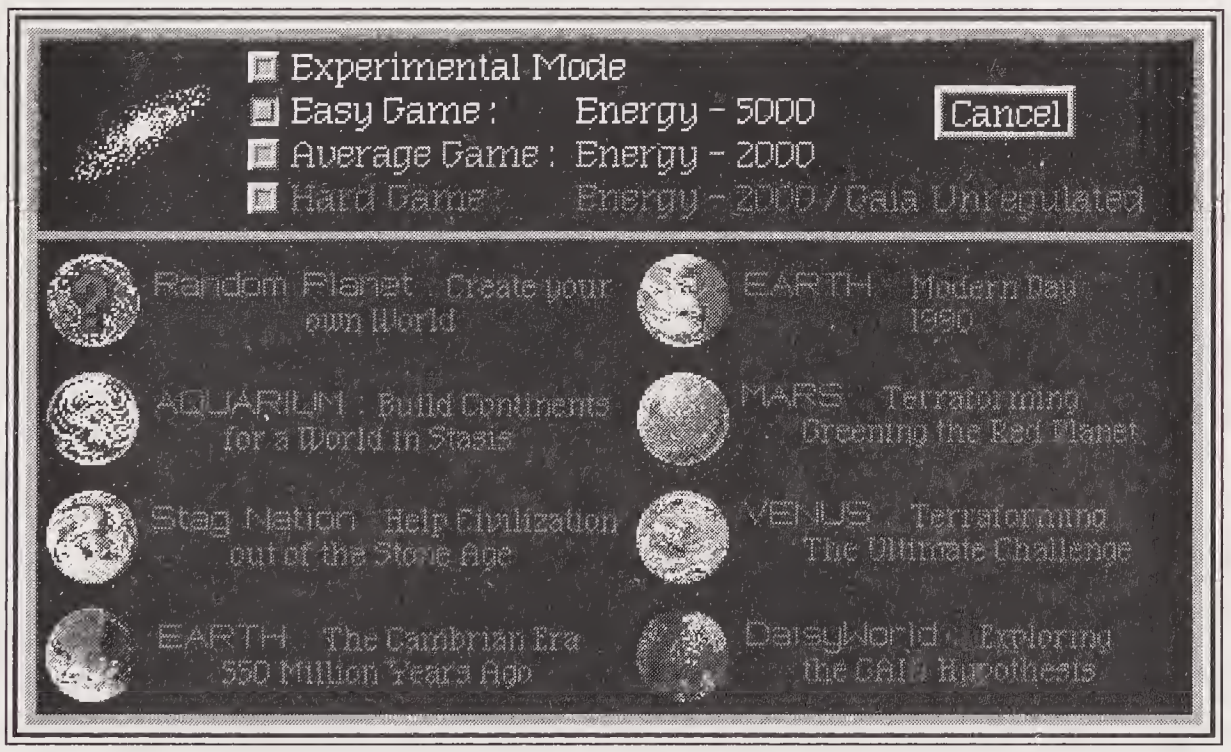
Displays the SimEarth message that you see when you first start the game.

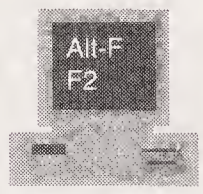
File Menu

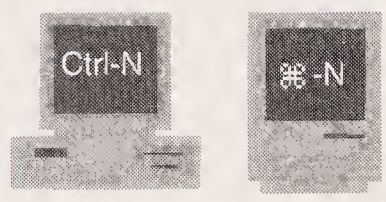
The File menu contains specific options for starting new planets, saving planets, printing planet images, and quitting the game.

New Planet

Select New Planet when you want to start from scratch. When you select New Planet, you'll see a special dialog window that offers eight different scenario choices as well as four different modes of play.







Modes of Play

Easy

In the Easy mode, you get 5000 Energy Units (EU) to spend. Energy you expend will replenish slowly, but you can never have more than 5000. Gaia regulation is on, meaning that the planet will have a tendency toward stability even if you don't do anything. The Model Control Panel settings are normal (about 50%).

Average

In the Average mode, you get 2000 EU maximum. Some of the Model Control Panel settings are randomized, but shouldn't be far from their normal settings. Gaia regulation is on.

Hard

In the Hard mode, you get 2000 EU, many of the Model Control Panel settings are randomized, and some may be far from their normal settings. But the news gets worse. Gaia is nowhere to be seen. She must have gone on vacation. Anyway, you have to run the whole show. Good luck.

Experimental

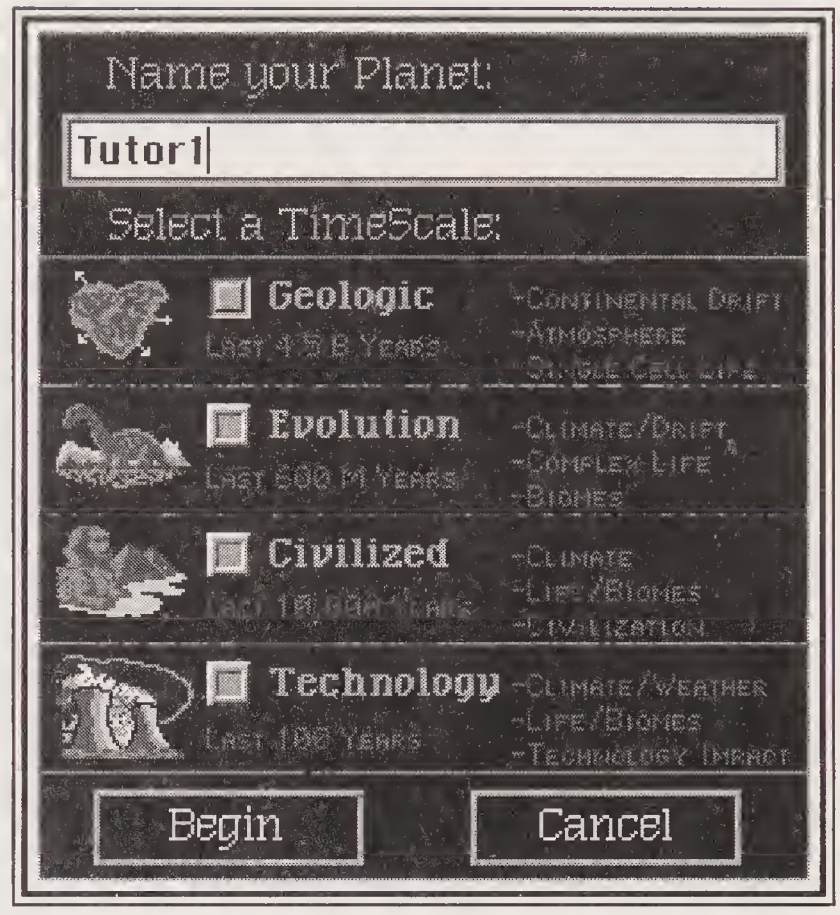
This is the one you'll really like for getting your jollies. You've got no energy budget at all and Gaia is there to help you along as well. Use this mode to try just about anything you want. For instance, in Experimental mode, you could cover the planet in a carpet of Nanotech cities or drop hordes of animal life on the continents. Do what you like. That's what Experimental mode is for.

On a more serious note, Experimental mode is also useful for testing strategies that you'll later try in one of the more limited modes of play. Here, if you make a mistake or two you can still recover. Sometimes in the other modes a mistake can be hard to correct.

SimEarth Scenarios

SimEarth comes with several pre-set simulations—Random Planet, Aquarium, Stag Nation, Earth (Cambrian), Earth (Modern), Mars, Venus, and DaisyWorld. In this section you will find a brief description of each of these scenarios. For

more detailed information about each of them, including tips for how to play them, see *Part III: The Simulations*.

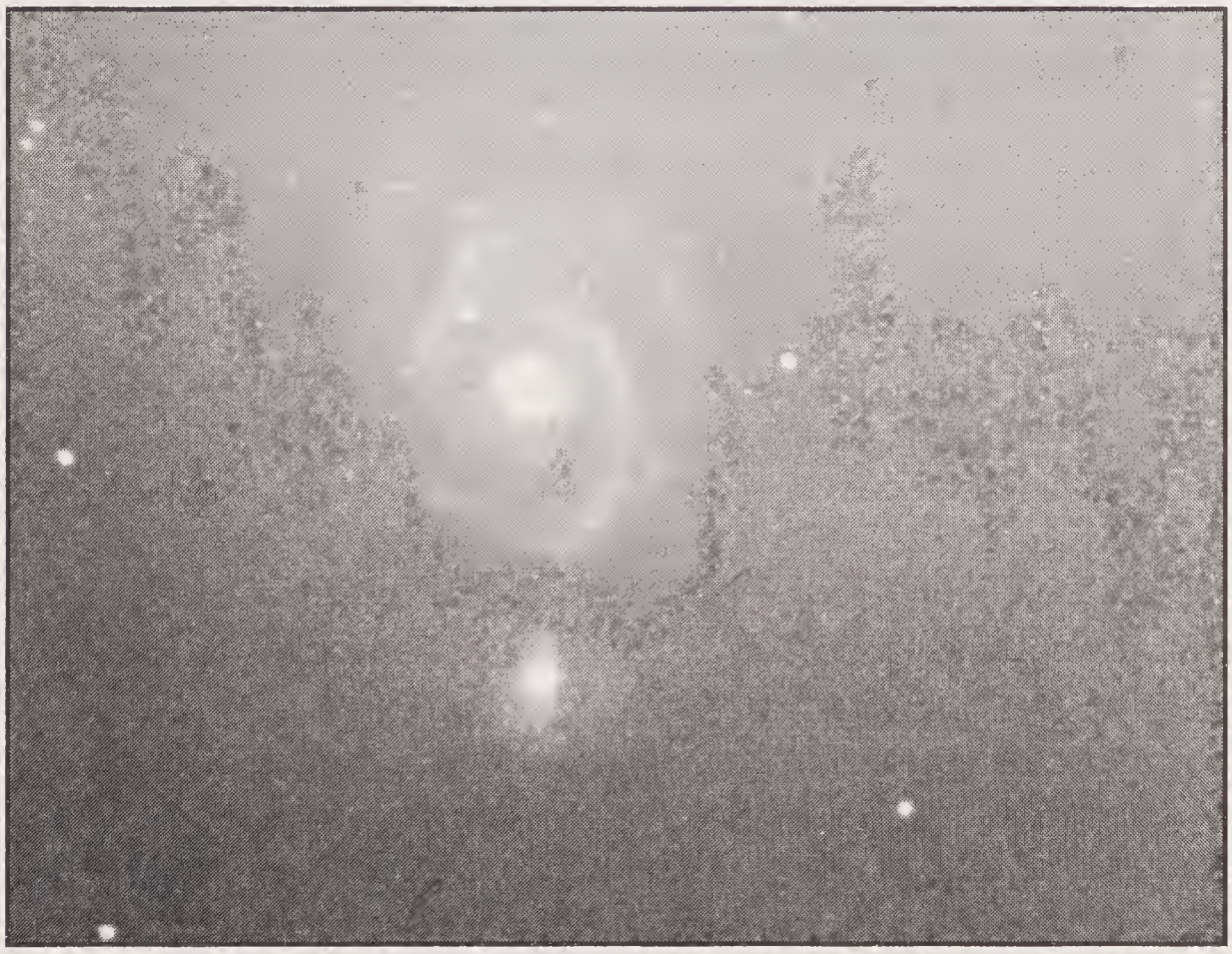


Random Planet

The Random Planet scenario lets you start off new with a randomly generated planet. Because the planet is randomly generated, the results of each game will vary, and though trends may exist, each new planet will tend to develop differently from another.

If you choose the Random Planet option, you'll have the option to start the simulation in one of four time scales—Geologic, Evolution, Civilized, or Technology. These four time scales conform to the periods you'll experience during the game if you start from the Geologic time period and play all the way through the game.

Geologic Time Scale



The Geologic Time Scale begins when the planet has newly formed and is still a molten mass of liquified rock. It is only recently (in geologic time) that a huge cloud of gas condensed and lit up in a vast thermonuclear reaction, signalling the birth of a new star. Circling the star are other lumps of matter that are too small to light up. Close to the star, the lighter,

volatile elements are swept away by the surge of power from the center of the cloud as it ignites. The lumps that remain form the rocky planets. Farther away, the gases stay within the gravitational sway of their smaller clouds and the gaseous planets like Jupiter, Saturn, Neptune, and Uranus take shape.

Gas giant, Jupiter.

This is an interesting period to watch. Though it is difficult to be positive of events that long ago, science has been able to make informed guesses.

On Earth, there is no life, no liquid water, and an atmosphere is just beginning to form from the activities on the surface. Radioactive materials condense in the core and create incredible heat. It's nothing compared to the blazing furnace that lights the sky, but in combination with later extraterrestrial impacts, it becomes hot enough to melt the surface and turn it into a veritable sea of lava.

One of the most probable events during this time is called the Great Bombardment. After the formation of the Sun, the planets were smaller than now, but were larger than the other objects in the solar system. Still, there remained a swirling mass of metallic planetesimals surrounding the newly-lit star, and these banged into each other and into the new planets, hitting with immense force. The planets grew in size. The scars from these impacts can still be seen on some of the outer planets and on the Moon. Here on Earth the forces of erosion and the reformation of land through the tectonic

plate activity have reshaped the topology constantly over the years. Evidence of the Great Bombardment is seen mostly in the abundance of heavy materials on the planet that came from extraterrestrial origins.

On Earth, the impacts of the planetesimals and the increasing pressure raised the heat of the planet, and eventually the entire world was a molten sphere of rock and metal. The heavy metals, in particular iron and nickel, migrated to the center of the sphere, forming a heavy core. The lighter, rocky elements, floated to the surface and, in time, they cooled and formed a crust.

Mars' moon, Phobos, shows what could have happened to smaller planets and moons during the Great Bombardment.

As the crust formed, so, too, another important feature of our planet also formed. This was the atmosphere. As the elements in the molten planet moved and reformed, gases escaped in a process called outgassing. You can watch the atmosphere form by opening the Atmospheric Composition Graph during the early part of the Geologic Time Scale.

Time passes very quickly during the Geologic Time Scale. Each cycle or "tick" of the game clock covers 750 million years. Therefore, the planet will cool quickly and begin to form land masses and eventually oceans. The most significant events of this period include:

- the development of an atmosphere suitable for life (but not yet oxygen-breathing life).
- the formation of oceans through condensation and the formation of land masses through volcanism.
- the formation of single-celled life.
- the development of photosynthesis and the resulting shift of the atmosphere to one containing significant amounts of oxygen (aerobic).
- the formation of tectonic plates which cause the continents to drift and constantly reform the planetary surface.

The Evolution Time Scale

Once the oxygen breathing single-celled creatures had changed the world, it was a matter of time before these cells found ways to combine to form larger, more complex life forms. The development of multicellular life begins the period that SimEarth calls the Evolution Time Scale. It is at this point that plants evolve and begin to colonize the land, multicelled creatures begin to swim in the seas, and, finally, animal life invades the land and begins new experiments in evolution.

The passage of time slows in this time scale. Now each cycle covers only 250,000 years. However, time still passes quickly enough to watch the continents drift some more. The atmosphere continues to develop to approach its modern day proportions.

When the Cambrian period begins, plants start to colonize the land and scrub the carbon dioxide from the air. This can cause some far reaching effects. Watch what happens if you don't interfere with the simulation. Or try to stabilize the planet and counter the trends.

When you first begin this period, the planet may begin to heat up rapidly. This is not likely to have happened, and really springs from the way the computer model works. Anyway, the planet will cool down quickly as plants spread out over the land and CO_2 levels fall. So you should be able to ignore the rising temperatures and prepare for ice age conditions that will follow unless you take some appropriate action.

Key events that take place during this period:

- continents continue to drift.
- the atmosphere approaches the modern mix of gases.
- plants spread out over the land.
- ice ages will occur unless acted upon by outside forces.
- multicellular life forms continue to evolve.
- creatures grow in intelligence and begin the journey toward sentience.

The Civilization Time Scale

Intelligent mammals—what we call humans or Homo Sapiens—have been around only a very short time geologically. The earliest Stone Age artifacts date back as much as 500,000 years ago, though Man first appeared probably about two million years ago. The Stone Age was the longest period of Man's history and lasted until perhaps 6000 years ago when metals were used regularly. Before that, civilization progressed from early cave dwelling savages to organized cities based on agriculture. Once metal working became common, the pace of human development increased dramatically. In the six thousand or so years since we discovered metals, we have evolved to the current state of technology, overpopulation, and complex global socio-political culture. We have, in that incredibly short time, come from a species more or less in harmony with and at the mercy of the elements to one that is actually changing the forces that govern our planet.

In SimEarth, it isn't always mammals that evolve to intelligence. Often it will be other life forms that reach intelligence. However, each will follow the same basic path that we did.

Time in the Civilization Time Scale is much slower than it was in the previous time scales. Now time moves ten years per cycle.

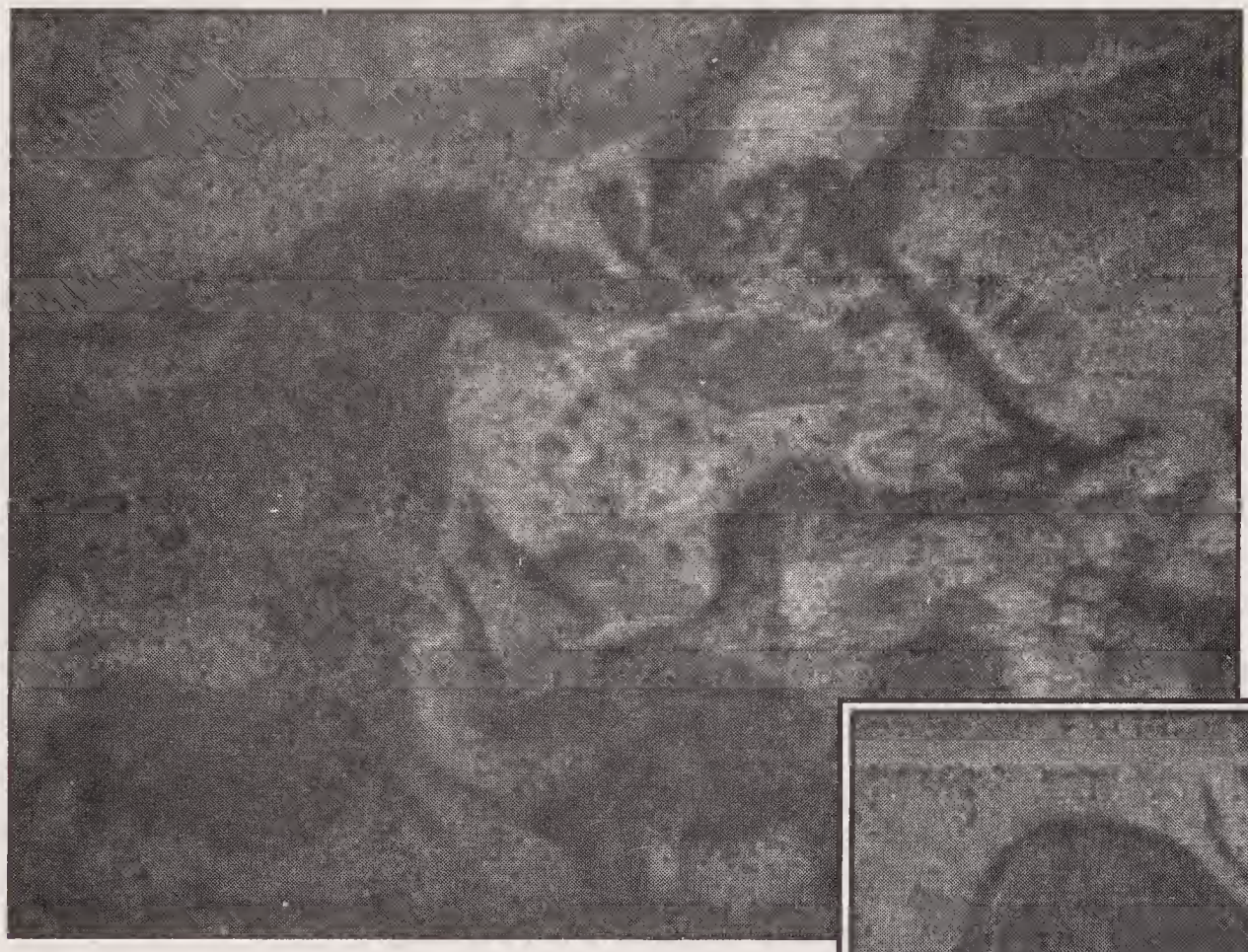
The Technological Time Scale

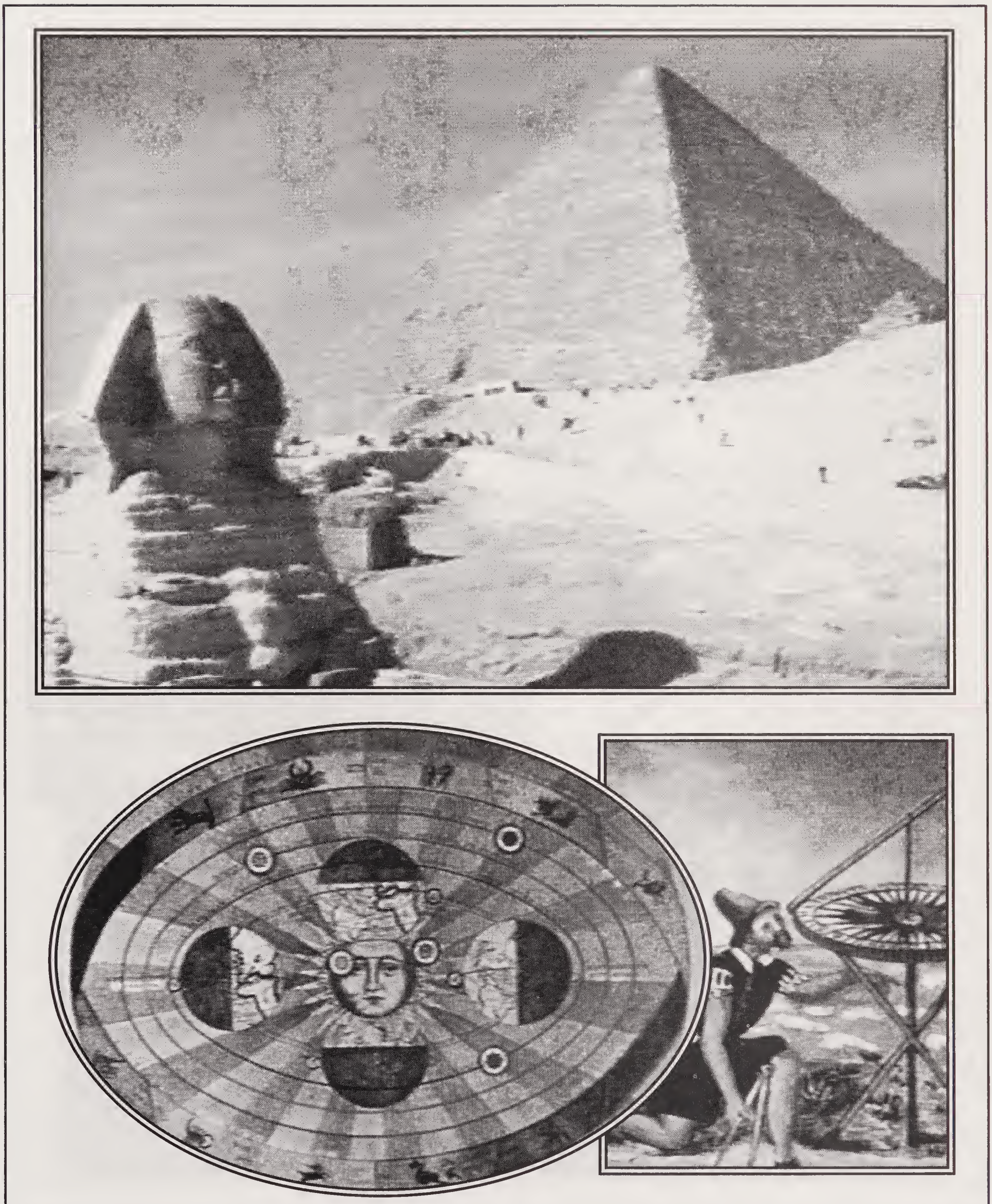
In this time scale, time moves at a tenth of a year per cycle. This is actually a little more than a month at a time. In the Technology Time Scale, seasons actually change, but other events like continental drift, for instance, are happening too slowly to see.

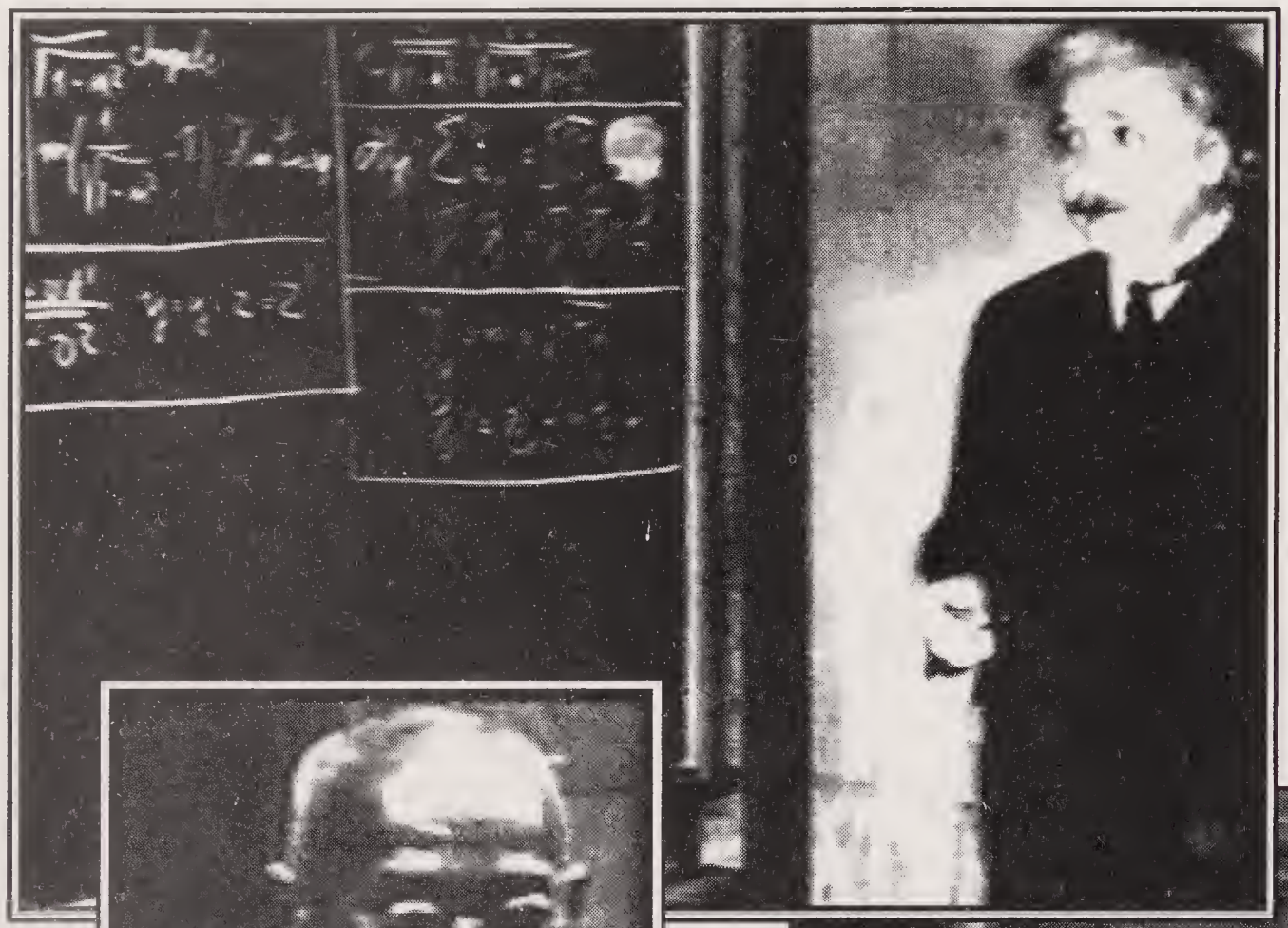
The Industrial Revolution marked the beginning of one of the fastest changes this planet has seen. Where previous changes took thousands or even millions of years to take place, these changes in life, civilization, and even to the planet itself were to take place in a matter of less than two hundred years. The process is still on-going, and we don't know what the end result will be. But the Industrial Revolution may be fairly called a revolution because it marked an extremely rapid change in human development.

It has been said that an average person of today's society processes more information in a year than people of the

CIVILIZATION







We should all be concerned with the future because we will have to spend the rest of our lives there.

–C. F. Kettering

Middle Ages processed in a lifetime. As a result of the Industrial Revolution, we have progressed into new ages of energy and information. Our pace of life is unlike anything seen on this planet before. We fly at supersonic speeds to anywhere on the globe, and through our satellites, we talk to each other almost anywhere. We stand at the doorway to space travel, and many of us dream of the adventure of outer space.

There was a time when young people dreamed of clipper ships crossing oceans to new lands. Now we look toward an unknown even more vast. Will we master the secrets of energy and reach the Nanotech Age? Will we solve our political, economic, and environmental dilemmas and reach the Exodus as postulated in SimEarth? Once we leave the Atomic Age in this simulation and step into the Information Age, we are writing new history. Nanotechnology is still a science fiction, not a science fact. But what we can imagine, we can do.

In SimEarth, you have the opportunity to imagine and perhaps to reach out for the stars. But you have to solve some of the technological world's problems. In particular, you must deal with rising populations and the tensions they can create. You must deal with sickness and with war and with industrial pollution. The model is certainly simplistic, but at least you get a taste of the reality. More importantly, perhaps, you get an opportunity to succeed.

Key challenges in the civilization and technology time scales:

- keep climate relatively stable.
- decide what energy sources will be used.
- decide how to allocate the energy.
- keep population growing.
- keep technology growing.
- control the levels of war and plague.
- reach Exodus.

Consider that people are like tea bags. They don't know their own strength until they get into hot water.

—Dan McKinnon

AQUARIUM

Can you take this water world and make a suitable place for life and civilization to flourish? The sky's the limit.

Speaking of Aquariums:

Ocean Resources and Ocean Management

The ocean is not just a great body of water, the object of poetry, surfing, and mediocre paintings. It is the wellspring of life on Earth and it is one of the most important elements in the puzzle of the Earth. It is a vast repository of food, a storage medium for important atmospheric gases, and a gigantic buffer that contributes mightily to the stability of our climate. In fact, being that the seas cover about 70 percent of the planet, some might suggest a more appropriate name would be Ocean.

But because we are a land-based species, we call our home Earth and we view the oceans as mysteries and barriers. We are still learning about the complex behavior of the great water world. We continue to discover new and sometimes very surprising facts about it. Being able to see the water from satellites in a variety of different spectra offers insights that no Earth-bound scientists and explorers could have obtained. And our ability to plumb the depths of the oceans with new devices has even helped us discover a whole new kind of life.

The Persian Gulf before it was defiled for political reasons.

However, in addition to being a source of discovery, of mystery, and of significance on a global scale, the oceans are resources. They are mines that we prospect for food, for minerals, and for energy. And it seems to be common conception that the oceans are limitless, inexhaustible, and imperturbable. And for the people who lived even fifty years ago, that may have been a reasonable assumption.

However, today we have begun to have a significant impact on the seas, and we are learning that their resources are neither inexhaustible nor imperturbable. In fact, we have found ways to threaten many of the key elements in the living ocean and are in the process of destroying many of the planet's most majestic creatures, simultaneously decimating whole populations of fish with no regard for future consequences.

The oceans of the world, though they bear different names, are, in fact, one continuous ecosystem. The currents that abound in the oceans are a circulatory system that, with the winds of the atmosphere, determine climate and help distribute the elements necessary to life. These currents are complex. Some, like rivers, flow unceasingly in one direction, looping around the land barriers, bringing warm water to colder climes and returning with colder water. Sailors have long known of these gyres and have used them to speed them from port to port whenever possible. An example of one such gyre is the Kuroshio (the Black Current) that sweeps up from the tropics, laden with the warmth generated there, past Japan and across the Pacific to start southward past the western edge of the United States. In the Atlantic is the Gulf Stream which follows a similar journey.

Other ocean currents move slowly, exchanging cold water from the poles with warmer tropical water in a slow cycle that may take centuries. This current, if it can be so called, is initiated at the poles. The colder water is heavier than the warmer water beneath it, and its burden of dissolved salts (left behind when water freezes) make it heavier still. So the water slowly sinks, and as it does so it makes its way toward the equator.

Ordinarily, this slow migration, or spreading, of the colder water simply moves and diffuses into the oceans, exchanging heat slowly. Remarkably, scientists have discovered that the oceans are layered, like many pages in a book, and that the different layers don't interact with each other very much. So the process of sinking colder water is very slow.

The ocean is an incredible source of energy if we can learn to use it. We've already started to find oil reserves under the sea, but that is not the extent of what the ocean can offer us. There are various technologies in development or in theory that could extract energy directly from the oceans—from the power of the waves themselves, for instance, or even from the differential of temperature that exists at the different layers.

Meanwhile, the movement of ocean currents above and below the surface continues. The arctic cold water moves below, slowly reaching for the equator. However, in certain places and at certain times, winds on the surface or the interaction of opposing currents may cause an upwelling of water from the bottom to the surface. When this happens, the nutrient-rich detritus of the bottom comes to the light and the creatures of the surface feast and proliferate. This is the cause of the plankton blooms that may cover hundreds of miles of the ocean and extend for many meters from the surface.

I've mentioned before the importance of plankton. There wouldn't seem to be much we could do to damage these fertile and extensive resources, but that may not be the case. As far as fishing is concerned, although people have started to recognize such planktons as potential sources of food proteins, we haven't yet begun to harvest in quantities sufficient to threaten the food chain. However, the damage we've done to the ozone layer may become a factor. The huge and growing ozone hole above the Antarctic occurs over one of the most important areas where plankton traditionally bloom. Known as the Antarctic Convergence, this is a major feeding ground for various whale species as well as penguins, seals, squid, and other creatures.

In other places, however, the fish are simply being depleted by giant fishing factories. These floating processing plants send out boats into fish-laden waters and simply catch everything in sight. Their methods have become so sophisticated that they are literally stripping the fish from the oceans with no regard for the future. All over the world the story is the same. Declining yields should tell us something, but it seems that the only response from the fishermen is to come up with more sophisticated methods.

It's ironic that ancient civilizations apparently knew more about the economics of fishing than modern society does. Ancient Hawaiians were reverent of their resources. They would let certain fishing areas lie fallow from time to time to replenish the stocks. They expressed their gratitude to the sea and respected it as a provider. Today's fishing industry is a wanton destroyer, out to feed hungry populations today without regard for tomorrow's catch.

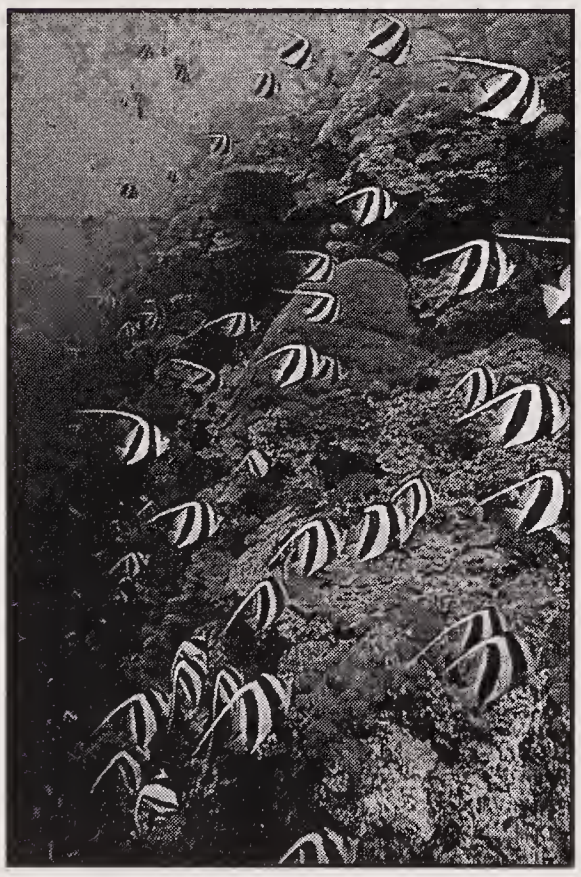
Part of the problem is that the oceans are considered to be "no man's land" as far as national ownership is concerned. Though there have been many attempts to regulate fishing on a global scale, they have been only marginally effective. The sad truth is that countries like

Russia and Japan, whose citizens depend heavily on fish, roam the world's oceans and ignore world opinion, not to mention practical reality. But the Russians and the Japanese aren't the only culprits. The rich northern countries also take a lot from the oceans, including tons of fish to make fish meal fertilizers.

Overfishing affects more than just a few people. On a local scale, many Third World countries are seeing their ocean resources taken for use in countries thousands of miles away, and there's nothing they can do about it. They don't have a large voice among the world leaders. And of course, the other creatures of the sea have no (political) voice at all. Yet, if we've learned anything, we've learned that all life is connected. If we overfish in one place, it is going to have an effect elsewhere. Every school boy or girl knows that big fish eat little fish which eat littler fish, etc. But what happens when you disrupt the cycle? Eventually, you get something you hadn't anticipated.

You would think that we had done enough with the ozone hole and overfishing, but of course, we have more to offer. We have our garbage, our runoffs, our oil spills, and even our nuclear wastes. We are fouling critical areas of the oceans—in particular the reefs and mangrove forests—with pollutants of all kinds. Pesticides, herbicides, and nitrates from fertilizers are the contributions of agriculture. Our cities add both industrial and often untreated biological sewage to further foul the waters. In particular, industry contributes a virtual smorgasbord of pollution including toxic chemicals, heavy metals, oil, sediment from construction, and various plastics and who-knows-what other mysterious wastes. Then there's the effect of erosion from deforestation which can pile sediment over living reefs and bury them. And in the mangrove forests, simple logging can destroy the whole ecosystem in little time.

A healthy reef, but for how long?



Add to these pollutors some nuclear reactor runoff, oil refinery leaks, and the all-too-famous oil spills, and you have painted a pretty grim picture using our coastal waters as the canvas. Is this the best we can do? Must we continue to view the oceans as dumps and sewers and objects of endless abuse? In the mind of some alien creature, it might all seem funny, like an episode of the Honeymooners where Ralph Kramden was always ranting at Alice, but nothing seemed to faze her. To us, whose home is Earth, and who sprang from the ocean, the humor is a little dim.

Fortunately, our problems in the ocean are, for the most part, easily solved. With global cooperation and some intelligent planning we could eliminate the problems of our depleted fisheries. With better housekeeping and an attention to conscious living, we could eliminate our careless pollution. In fact, the oceans, as beneficent as they are, would most likely regenerate quickly compared to many other endangered elements of the world. One problem that has no immediate solution is the ozone hole. Nobody knows for sure what is going to happen with it, or what its real effect will be. We can only hope, study, wait, and see what happens.

Stag Nation

Civilizations need room to grow. Can you take this small Stone Age civilization and help it expand and settle the world? There are various ways to do so.

Earth (Cambrian)

Visit the Earth a few hundred thousand years ago. See the giant continent of Pangaea and watch it break up into the continents we know today. See what kinds of civilizations you can form while this is happening.

Earth (Modern Day)

Tackle the challenge of modern Earth.

Mars

Terraform Mars. See if you can make it suitable for life in 200 years or less.

Venus

Early astronomers used to hope that Venus would prove to be a place not unlike Earth. Instead it's not unlike Hell. Can you make it Heaven?

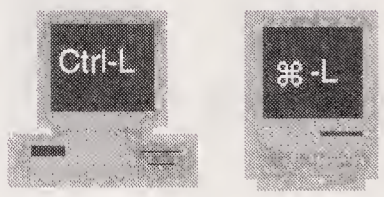
Daisyworld

The original demonstration of Gaia theory. Learn the basic principles of positive and negative feedback loops. See, in a simple model, how Gaia regulates herself.

Other File Menu Items

Load Planet (Command-L)

Loads a previously saved planet from disk. Choose the planet you want from the dialog box.



Save Planet (Command-S)

Saves the current planet at the moment you choose. If it is the first time you've saved the planet, you'll be asked to give it a name. Thereafter, each save simply replaces the former save.

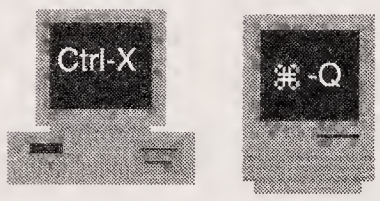
Save As...

If you have previously saved a game and want to save a different version of it, use the Save As... command. You can give it a new name. Other saved versions of the current game remain intact and unaltered on disk.

Snapshot (Print...)

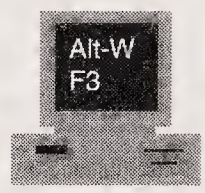
Use Snapshot or Print to print out your current Edit window in a format suitable for your computers. Only the black and white version of the Macintosh will print. On the IBM version, there are several options available, all of which are explained in the addendum that comes with SimEarth.

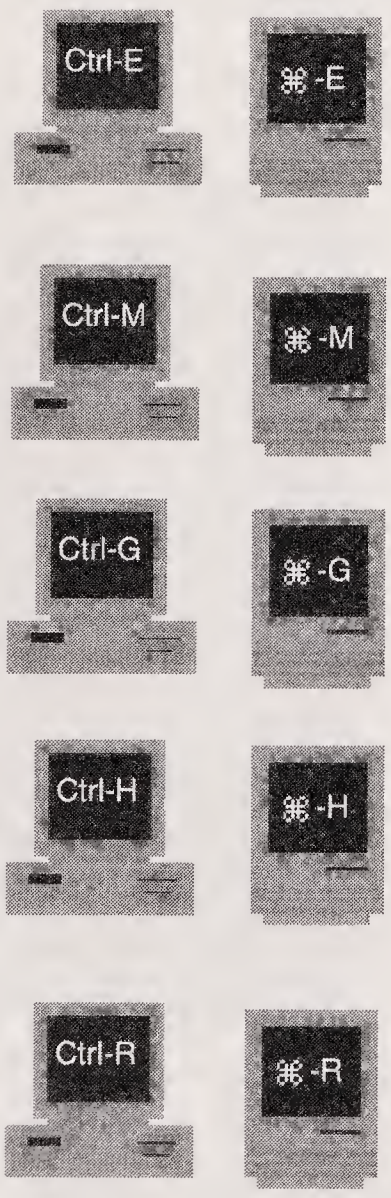
Quit



Return to the operating system and stop playing SimEarth—but why?

WINDOWS MENU





Edit

Opens the Edit window if it isn't already open. Brings it to the front if it is.

Map

Opens the Map window if it isn't already open. Brings it to the front if it is.

Gaia

Opens the Gaia window if it isn't already open. Brings it to the front if it is.

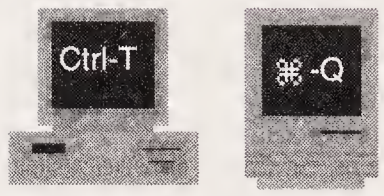
History

Opens the History window if it isn't already open. Brings it to the front if it is.

Report

Opens the current Report window if it isn't already open. Brings it to the front if it is. The Report information changes from one time scale to another.

Tutorial



Opens the Tutorial window if it isn't already open. Brings it to the front if it is. Follow the Tutorial to get a quick start in SimEarth.

Glossary

Opens the Glossary window if it isn't already open. Brings it to the front if it is. The Glossary window contains definitions of many of the terms used in SimEarth.

MODELS MENU

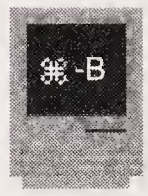
Geosphere

Opens the Model Control Panel window if it isn't already open and selects the Geosphere Model Control Panel. If the Model Control Panel window is already open, activates the Geosphere Model Control Panel.

Atmosphere

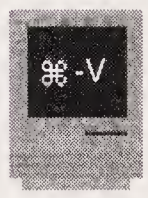
Opens the Model Control Panel window if it isn't already open and selects the Atmosphere Model Control Panel. If the Model Control Panel window is already open, activates the Atmosphere Model Control Panel.

Biosphere



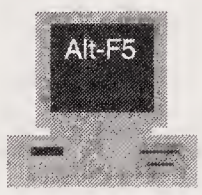
Opens the Model Control Panel window if it isn't already open and selects the Biosphere Model Control Panel. If the Model Control Panel window is already open, activates the Biosphere Model Control Panel.

Civilization



Opens the Model Control Panel window if it isn't already open and selects the Civilization Model Control Panel. If the Model Control Panel window is already open, activates the Civilization Model Control Panel.

GRAPHS MENU



Air Sample

Opens the Atmospheric Composition Ratio graph if it isn't already open. Brings it to the front if it is.

Biomes

Opens the Biome Ratio graph if it isn't already open. Brings it to the front if it is.

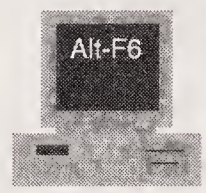
Life-Forms

Opens the Life Class Ratio graph if it isn't already open. Brings it to the front if it is.

Technology

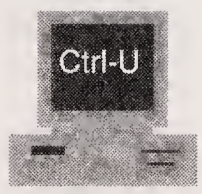
Opens the Technology Ratio graph if it isn't already open. Brings it to the front if it is.

OPTIONS MENU



Goto Events

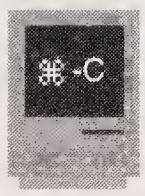
If you're worried that you'll miss the key events happening on your planet, try selecting Goto Events from the Options menu. When the Edit window is active (in front), the view in the Edit window will switch to the location of any events taking place. However, be prepared for some fast movement. Events can happen with amazing rapidity in SimEarth. You'll feel like the ultimate world traveler in a matter of moments. I wonder if there are any frequent traveler benefits?



Update Background

If the simulation is moving too slowly for you, this is a way to speed it up. The program defaults to the Update Background mode. This means that all open windows are animated and update during each cycle of the game.

If you want to speed things up, select Update Background to remove the checkmark from it. Now only the front window will update and animate. The drawback to this mode is that you can't track information in other windows like the History window or the graph windows while watching the activities in the Edit window. However, if you're impatient and want to move things along, this option may be useful.



Compress Edit Screen

If you don't have enough room on your monitor to see all the details you want in the Edit window, Compress Edit Screen

lets you see more of the map in the same space by displaying only every other tile of the map. This actually increases the area you can view by four times. Of course some of the detail is missing.

Music

The music is normally active during the game, and you'll hear the various songs that play when key events take place. However, you can turn off the music if you want to listen to your favorite rap or rock or whatever you like.

Sound Effects

Sound effects are normally on, but you can turn them off with this item.

Messages

Messages are useful for reminding you of the situation on the planet, but if you're tired of being told that your planet is overheating or Life Quality is Hellish, you can turn Messages off.

AutoScroll

This option will cause the Edit window to scroll if you are currently using one of the Edit window tools. For instance, if you wanted to drag a Stone Age city from the North Pole to the South Pole, you could simply use the Move tool to grab the city and drag to the bottom of the window. The window would scroll until you reached the South Pole. Then you could release. If AutoScroll is off, this won't happen.

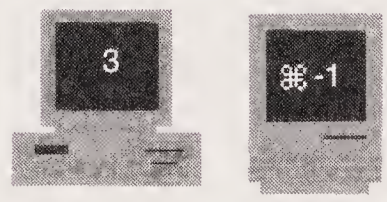
Save Options & Windows

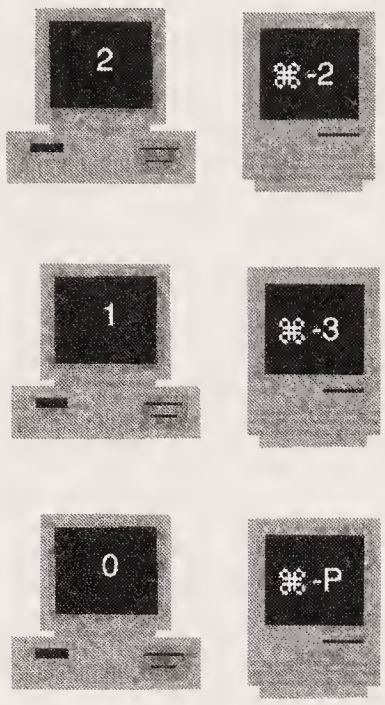
You can save the current setup of options and open windows so you don't have to reset everything the way you like it each time you play the game. When you save these options and windows, the same configuration will load each time you play SimEarth.

Speed Menu

Fast

This option makes time pass as quickly as your computer will allow it to.





Moderate

This sets the speed to about 75% of the Fast speed.

Slow

This sets the speed to about 25% of the Fast speed.

Pause

Use this item to stop the simulation in its tracks. You can still use all the tools and menus, but time no longer passes on the planet. You could create a world-wide catastrophe using Pause. For instance, if you were feeling particularly destructive, you could Pause the game and drop a hundred meteors on the planet's surface. Then see what happens when you restart the simulation.

Relative Date

This item shows the time that has passed since the beginning of the current time scale. It starts over when you reach a new time scale.

Absolute Date

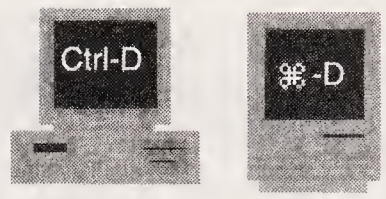
This shows the number of years since the cooling of the planet. This is absolute geologic time. If you play a scenario that starts in one of the later time scales, the program estimates the appropriate amount of time preceding that moment.

DataSound Menu

Tone Monitor

The Tone Monitor is useful when you are trying to keep track of some aspect of the simulation, but you can't always be checking the graphs or you're busy doing other things. The Tone Monitor plays an intermittent tone that represents the value of the item you are tracking. For instance, if you want to track how well your civilization is doing, you might set the Tone Monitor on and choose Civilization (also on the DataSound menu). Then, if the population of your people was falling, you'd hear a lower tone. If it is increasing, the tone will be higher.

Play Data Song



This option reads the current information about the data item you've selected for 32 evenly spaced areas moving from the top to the bottom of the map. It then averages the values and plays a song based on those values. This is more for fun, but you can play it any time you want. It does give a basic idea of the temperature ranges present on your planet.

You can use both Tone Monitor and the Data Song with one of seven different aspects of the simulation:

Altitude plays a tone for different levels of altitude on your planet. Basically, it measures the altitude moving from the north to the south of the map, taking an average along a longitudinal stripe.

Air Temperature plays a tone to represent the average air temperature of the planet. The Data Song is a representation of the temperature range from the North Pole, through the equator, to the South Pole.

Rainfall plays a tone to represent the average rainfall of the planet. The Data Song is a representation of the rainfall ranging from the North Pole, through the equator, to the South Pole.

Sea Temperature plays a tone to represent the average sea temperature of the planet. The Data Song is a representation of the temperature range in the oceans from the North Pole, through the equator, to the South Pole.

Biomass plays a tone to represent the current biomass of the planet. The Data Song is a representation of the levels of biomass in different areas ranging from the North Pole, through the equator, to the South Pole.

Life plays a tone to represent the diversity of life of the planet. The Data Song is a representation of the diversity in different areas ranging from the North Pole, through the equator, to the South Pole.

Civilization plays a tone to represent the state of civilization on the planet. The Data Song is a representation of the levels of civilization in different areas ranging from the North Pole, through the equator, to the South Pole. It averages the civilization levels with the populations in each of those civilizations.

Biospheres

Are we destructive, undisciplined, ungrateful hairless monkeys intent on destroying our own home? Are we caught in a morass of apathy and bureaucratic inaction? Or are we an evolving intelligence who will soon mature into something more, who will realize the future seen by visionaries, but little realized so far? Is it already too late for us? Have we set in motion our own destruction? Or have we misinterpreted the dangers facing us? Perhaps we'll solve the many global crises we now face, and then what?

These are some of the questions I ask myself as I write this book. And it seems to me that there are two basic answers. One is that we are, indeed, irresponsible and we will be lucky to survive at all. The other, more sanguine thought is that we are just young and learning. That we are discovering our power so quickly that we haven't yet learned to use it. And perhaps we will be the ancestors of a future race of people who travel through space, terraform worlds, and carry the miracle of life to faraway places that we only imagine today.

These thoughts are not uniquely my own. Others dream these dreams, and believe in them. It is encouraging that even our own government, which does not always seem to have its priorities particularly in line with my version of reality, is looking forward to manned space stations and possibly to a long-term project to terraform Mars. What is most encouraging about the Mars project is the possibility that we might cooperate as a global community in accomplishing the task. Though President Bush would like to see an American flag planted on Martian soil by the year 2020, I would like to see a global flag, or, perhaps no flag, just a promise of a new start.

If we could act as a global community we might start to grow up. If we could do away with warfare and invest our energies in our collective futures, we might find that our adventure is just beginning.

In his book *Biospheres*, Dorion Sagan makes a case for the eventual spread of humanity beyond Earth. He talks about the man-made biosphere as perhaps the seed that extends Gaia beyond the boundaries of Earth and on to other places. Looked at that way, the biosphere we know on Earth goes with us. We become the mechanism of reproduction that allows Gaia to reproduce herself. This is the hopeful, positive future. On the other hand, he warns, "People are not in charge right now. For the most part, we are just a tunnel-visioned, self-serving species, highly dangerous to ourselves and to a few other species, and fascinated by the technology we imagine is our own. Such delusions of grandeur and control go hand in hand with the development of powerful technologies, but they are frills to the overall biospheric structure. We exist because other oganisms cycle the biosphere with needed materials."

So we should realize our limitations, our position in the scheme of things, and our promise for the future. Another quote from Dorion Sagan: "From the viewpoint of long-term evolution, it seems incontestable that we must ground ourselves and our products in the ancient ways of Earth life if we are to survive. As a global civilization we must fall in with nature as one would fall in love."

A MESSAGE ABOUT THE ANCIENT WAYS

This is what Chief Seattle said as he prepared to turn his people's land over to the white man. It may serve as an indictment, an example, a judgement or an inspiration. Your choice.

The shining water that moves in the streams and rivers is not just water, but the blood of our ancestors. . . . Each ghostly reflection in the clear water of the lakes tells of events and memories in the life of my people. The water's murmur is the voice of my father's father.

The rivers are our brothers. They quench our thirst. They carry our canoes and feed our children. So you must give to the rivers the kindness you would give any brother.

If we sell you our land, remember that the air is precious to us, that the air shares its spirit with all the life it supports. The wind that gave our grandfather his first breath also receives his last sigh. The wind also gives our children the spirit of life. So if we sell you our land, you must keep it apart and sacred, as a place where man can go to taste the wind that is sweetened by meadow flowers.

Will you teach your children what we have taught our children? That the earth is our mother? What befalls the earth, befalls all the sons of the earth.

This we know: The earth does not belong to man, man belongs to the earth. All things are connected like the blood which unites us all. Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself.

One thing we know: Our god is also your god. The earth is precious to him and to harm the earth is to heap contempt upon its creator.

Your destiny is a mystery to us. What will happen when the buffalo are all slaughtered? The wild horses tamed? What will happen when the secret corners of the forest are heavy with the scent of many men and the view of the ripe hills is blotted with talking wires? Where will the thicket be? Gone! Where will the eagle be? Gone! And what is it to say goodbye to the swift pony and the hunt? The end of living and the beginning of survival.

When the last Red Man has vanished with his wilderness, and his memory is only the shadow of a cloud moving across the prairie, will these shores and forests still be here? Will there be any of the spirit of my people left?

We love this earth as a newborn loves its mother's heartbeat. So, if we sell you our land, love it as we have loved it. Care for it as we have cared for it. Hold in your mind the memory of the land as it is when you receive it. Preserve the land for all children and love it, as God loves us all.

As we are part of the land, you too are part of the land. This earth is precious to us. It is also precious to you. One thing we know: There is only one God. No man, be he Red Man or White Man can be apart. We are brothers after all.

—Chief Seattle

Part III

Simulations

Space isn't remote at all. It's only an hour's drive away if your car could go straight upward.

—Sir Fred Hoyle

Overleaf: Montage of planets showing Earth, the Moon, Jupiter, Saturn, and Neptune.

Part III
The Simulations

In this section, we talk about the simulations included with SimEarth. We assume that you already have some familiarity with SimEarth by the time you begin to read this section. If you are still pretty new to SimEarth, we recommend that you go through Part I, the Tutorial, at the beginning of the book to become more familiar with the way things work. If you just want to forge ahead, remember to use the SimEarth manual or Part II, the Reference, in this book if there's a tool or procedure you don't understand.

RANDOM PLANET

The Random Planet lets you experiment with an Earth-like planet generated randomly by the simulation. Its continents and oceans will be different from the Earth we know, but otherwise it will respond in the same general ways, depending on the level of difficulty you've chosen. You can begin a random planet from one of four time scales—Geologic, Evolution, Civilization, or Technology.

In the beginning of this book, we take you through a complete Random Planet scenario, beginning in the Geologic Time Scale and going all the way to Exodus. In general, Part I of this book gives you the guidelines for understanding the Random Planet scenario. However, the choices you can make

are almost limitless. You can use the Random Planet in a variety of ways.

Here are some ideas for using the Random Planet:

- Try different settings in the Geosphere Model Control Panel and begin with the Geologic Time Scale. See how each of the settings affects the resulting planet.
- Try using earthquakes and meteors to change the formation of continents due to continental drift.
- Try putting different kinds of life on the planet at different times.
- Try just watching the planet develop without any interference. Watch it several times, and chart the major occurrences. For instance, when do the oceans form? How about prokaryotes? Eukaryotes? Radiates? etc.
- See what happens when you create a world with lots of continental shelves. Or a world with mostly deep ocean.
- Try to create a stable, happy civilization. Is there a perfect balance between quality of life and society's viability? Can you create the perfect civilization?

One suggestion: For more stable planets, be patient. Beginning the Evolutionary Time Scale (Cambrian Age) too early leads to a more unstable planet. This is what we did on purpose in Part I to give you more experience with SimEarth at its wildest. However, there's really no hurry, and your civilization can start ideally any time after about 2.2 billion years.

On the next page is a chart you can use to mark the times when events occur while working with the Random Planet simulation. Another suggestion is to mark a line down the chart whenever an ice age occurs. If you play the Random Planet several times, you may start to see some patterns emerge. Then again, you may not. SimEarth can keep you guessing from time to time (so to speak). Try photocopying the following page, then running SimEarth without interference many times. See what results you get.

SimEarth Planetary Development Checklist

Oceans						
Prokaryotes						
Eukaryotes						
Cambrian						
Radiates						
Arthropods						
Trichordates						
Mollusks						
Insects						
Carniferns						
Fish						
Amphibians						
Reptiles						
Dinosaurs						
Mammals						
Stone Age						
Bronze Age						
Iron Age						
Industrial						
Atomic						
Info Age						
Nanotech						
Exodus						

AQUARIUM

The Aquarium planet is a water world. There is no land above water in this world. Life has evolved on this planet, but there is no land and without land civilization won't develop. How can you create land on this water world?

There are several ways to create land on the Aquarium planet. Some are pretty simple and direct. For instance, you can simply blow off some volcanoes. That will quickly create new land, although it might have adverse effects on some of the life forms in the oceans. Or you can use the Set Altitude tool and simply create continents with it. Write your name or a special message in continental land, or design an artistically pleasing world. Can you design a world especially well suited to life?

There are other, more subtle ways to create continents. Working with the Geosphere Model Control Panel, you can simply raise the level of Volcanic Activity and wait for the volcanoes to happen.

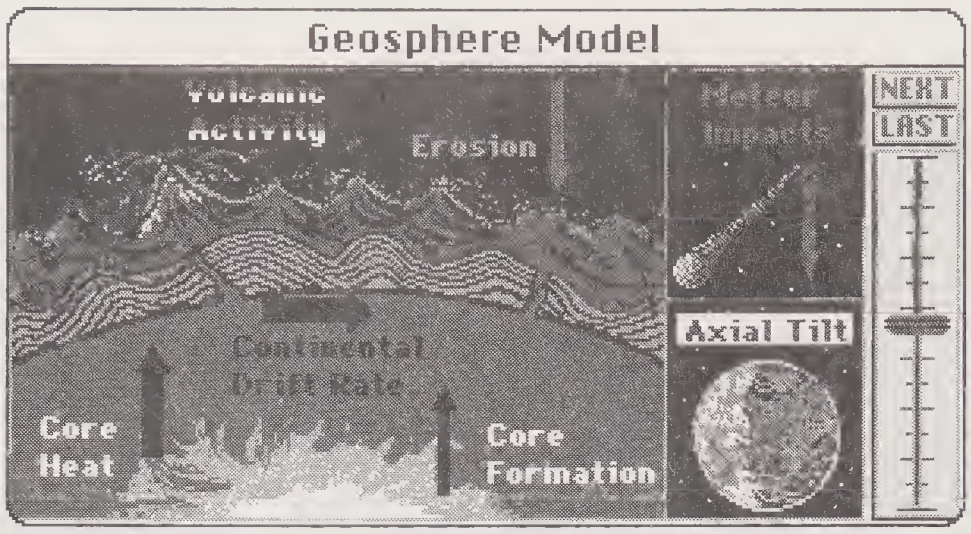
My favorite way to create new continents is to use a combination of Geosphere Model Control Panel settings and earthquakes. As long as you haven't started the Civilization Time Scale, you can let the continental drift form new planets in a more or less realistic way. Here's how:

1. **To begin with, select New Planet from the File menu and choose Aquarium from the available options.**

   To make things easier, use the Experimental mode (though you can use one of the other modes for more challenge).

2. **Open the Geosphere Model Control Panel.**

3. **Increase the levels on Continental Drift Rate and Core Heat. You might also decrease the level of Core Formation.**



These three settings will affect the magma flow rate and consequently the speed at which the continents will fly together.

4. **Now, on the Map window, select the Continental Drift icon (the third one from the left).**

   You'll notice that there are no arrows on the map. In fact, at the beginning of the Aquarium planet simulation, there is no continental drift... no plate activity. You'll soon fix that!

The idea of this experiment is to get the tectonic plates to crash together at different angles and head-on so they'll push land up out of the oceans and form mountain ranges that will eventually form continents.

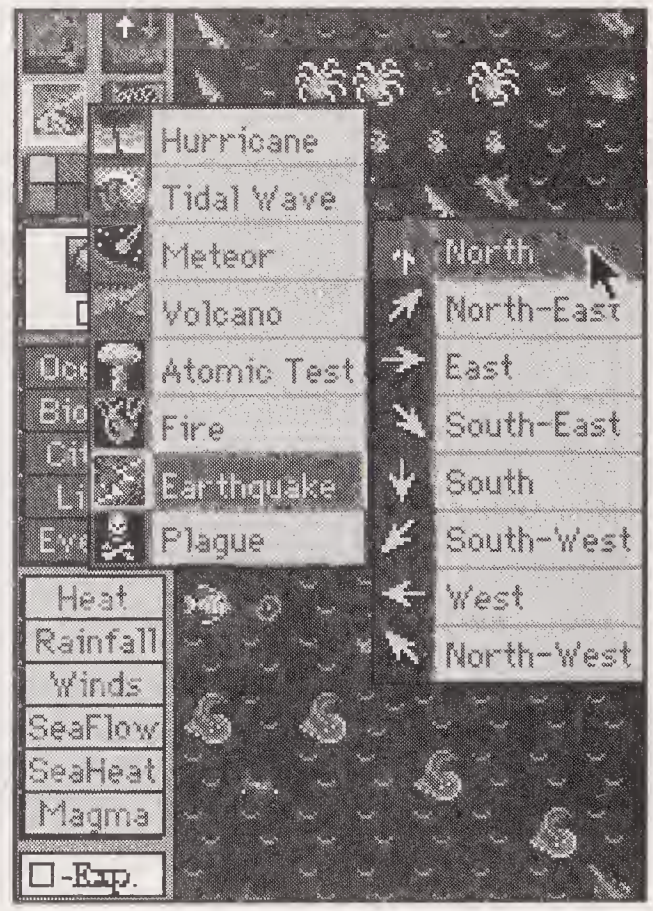
5. **Move the Edit Rectangle to a position on the map somewhere in the middle, to the south.**

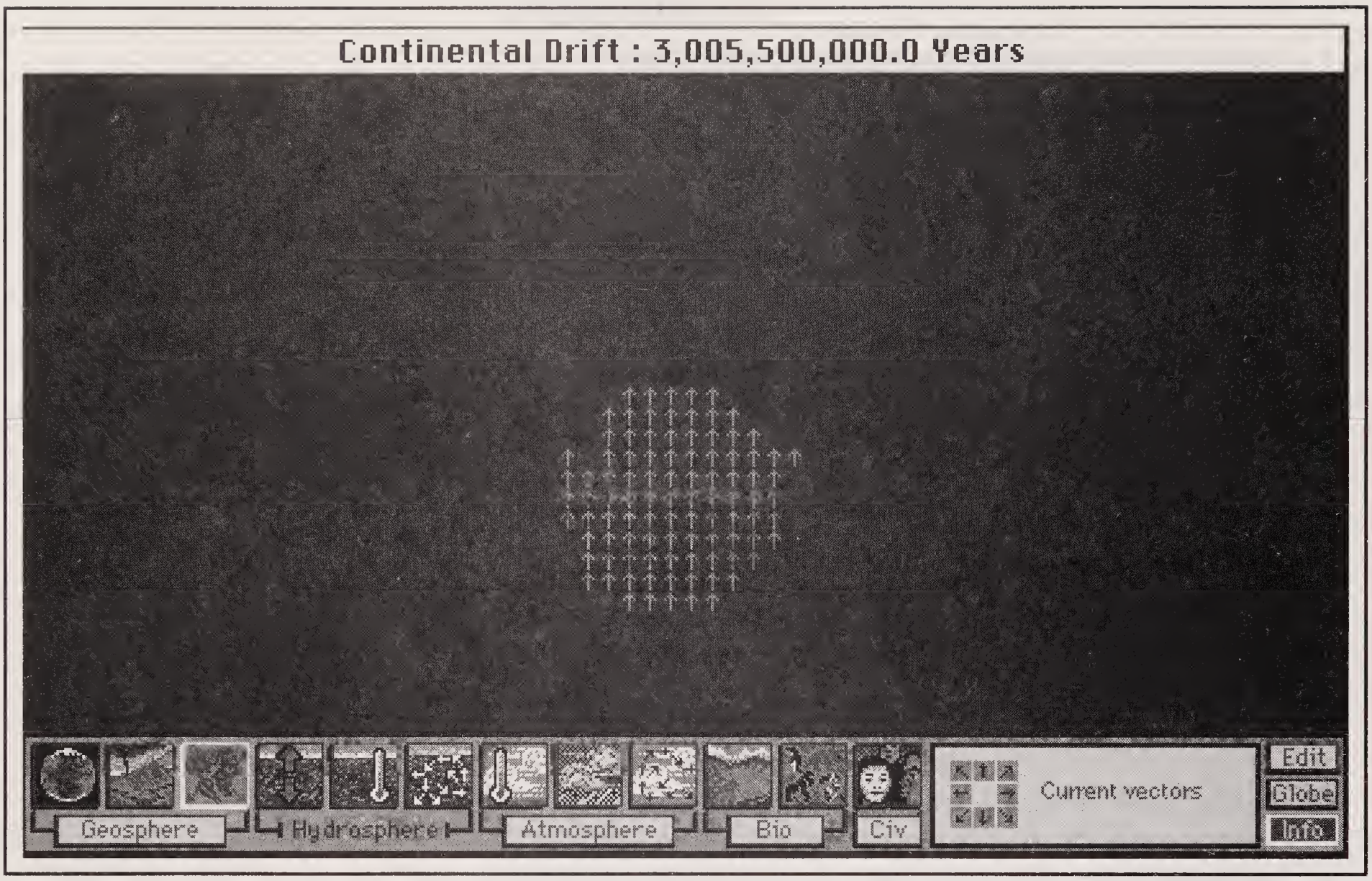
6. **Back to the Edit window, from the Event Trigger, select Earthquake.**

   You'll see a list of directions.

7. **Select North for the direction of the earthquake.**

8. **Click once in the Edit window.**





You've set off an earthquake whose energy is directed north. That causes the magma to begin flowing north as well. You should see a sort of circular area of northward-facing arrows in the Map window.

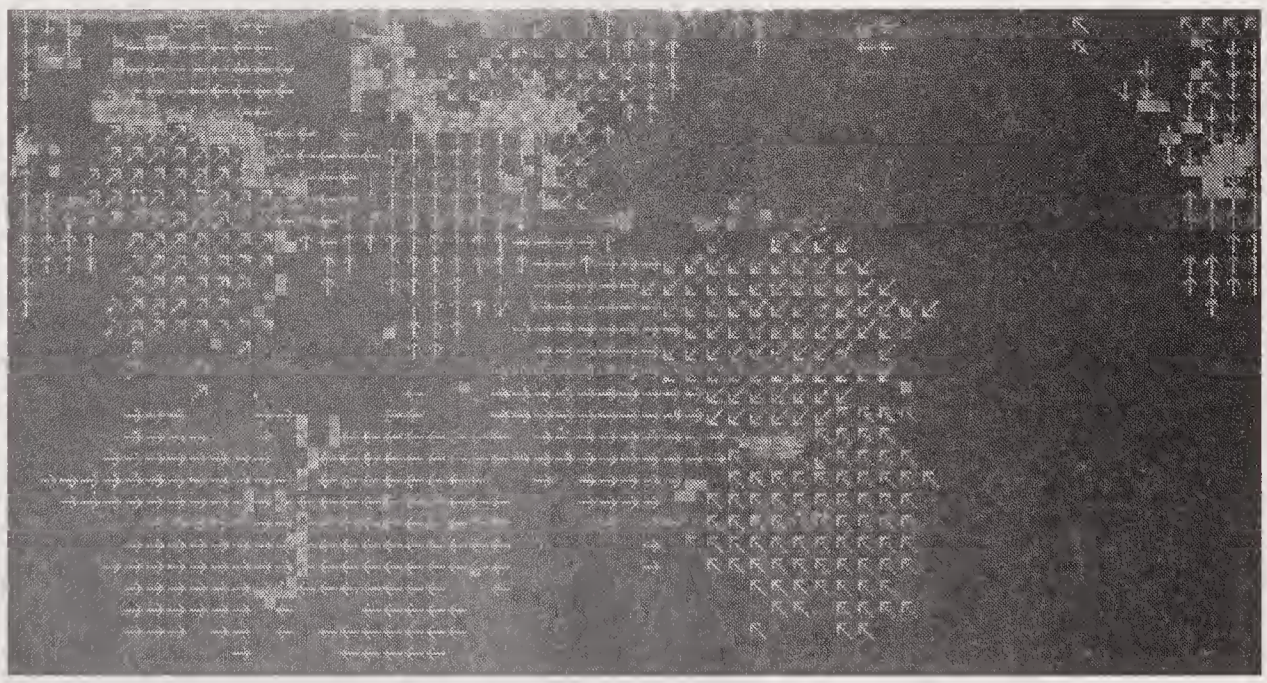
9. **Now use the Edit Rectangle to select a place directly north of your original one.**

10. **Return to the Earthquake option of the Event Trigger and choose South this time.**

11. **Now click in the Edit window to send a hunk of crust flying southward, toward the other section you just started northward.**

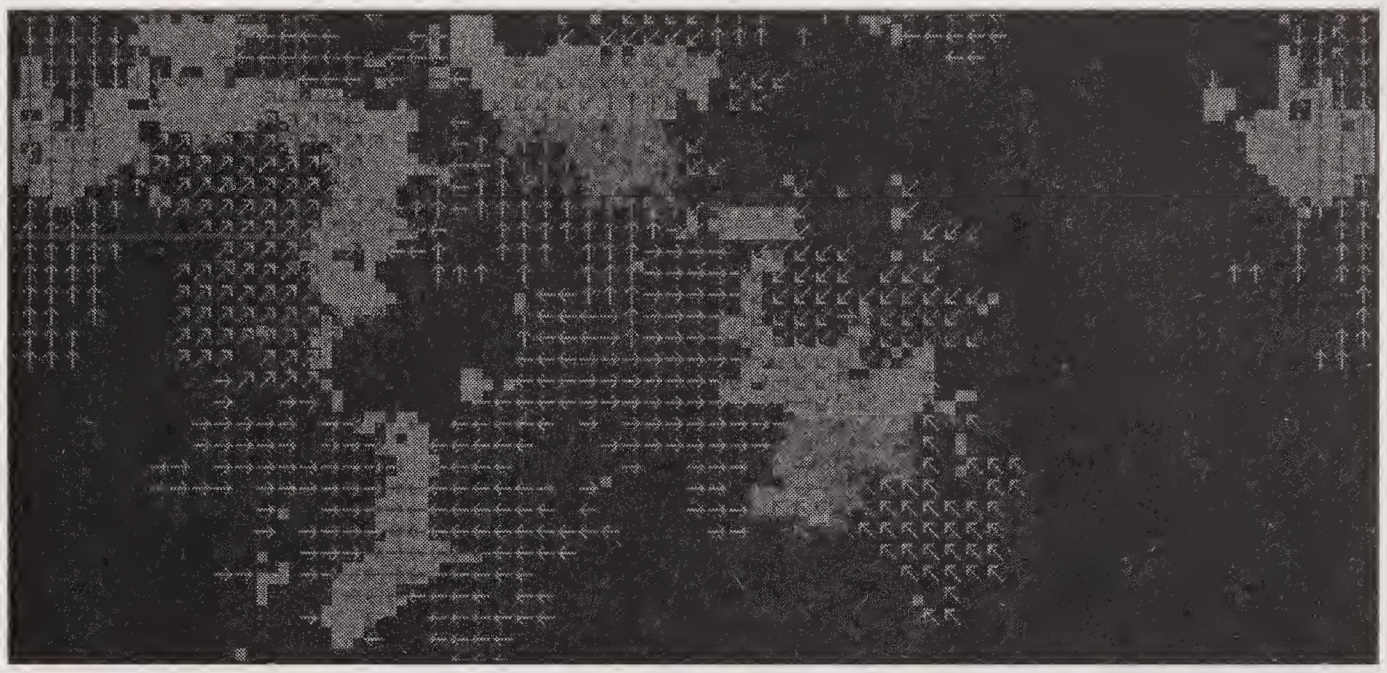
Now you've got two plates heading toward each other. Eventually, thousands of years later, land should begin to appear. But meanwhile, don't just sit there; start sending other earthquake torn sections at each other. You can set off earthquakes at angles to each other, as well. See what kinds of tectonic interfaces make the best continents appear over time.

Finally, once enough land appears, biomes will cover them and a new threat to your planet will appear. Now that green plants are taking carbon dioxide from the air, there may be sudden shifts in the carbon dioxide levels and even in the oxygen levels. Be ready to stabilize your environment or you may suddenly lose many species to sudden global cooling or warming.

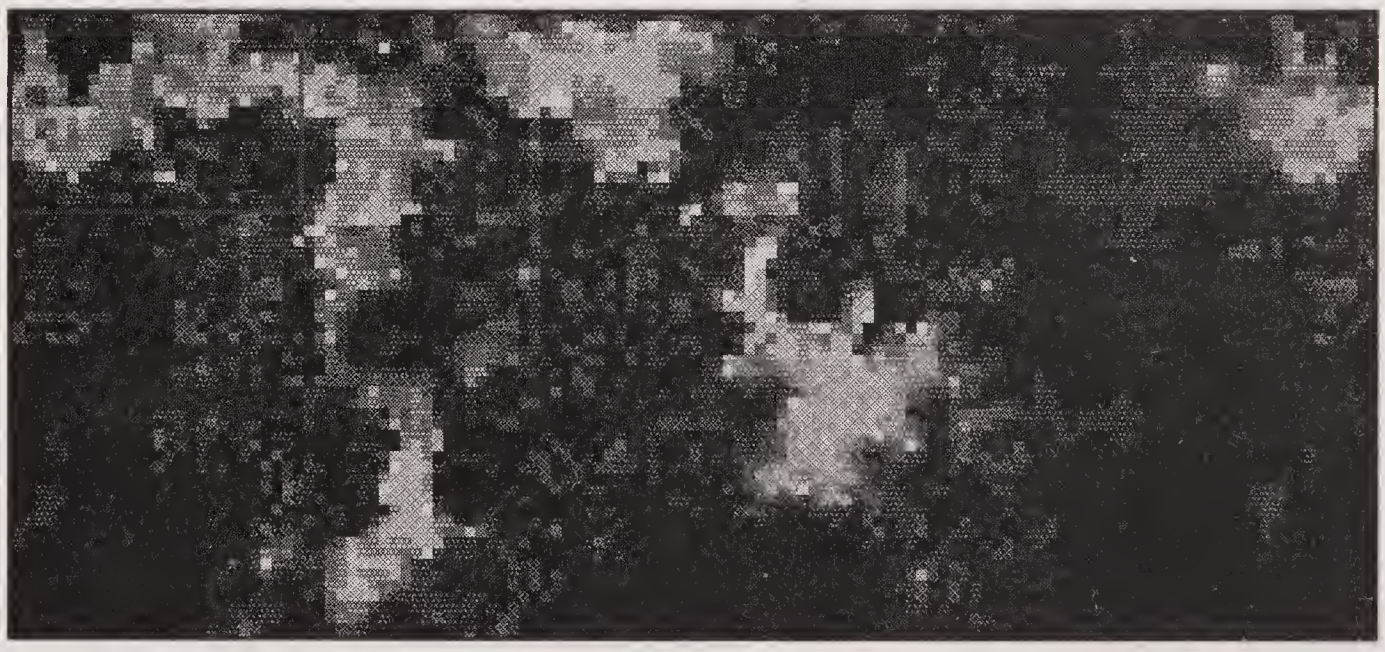


Early continents forming.

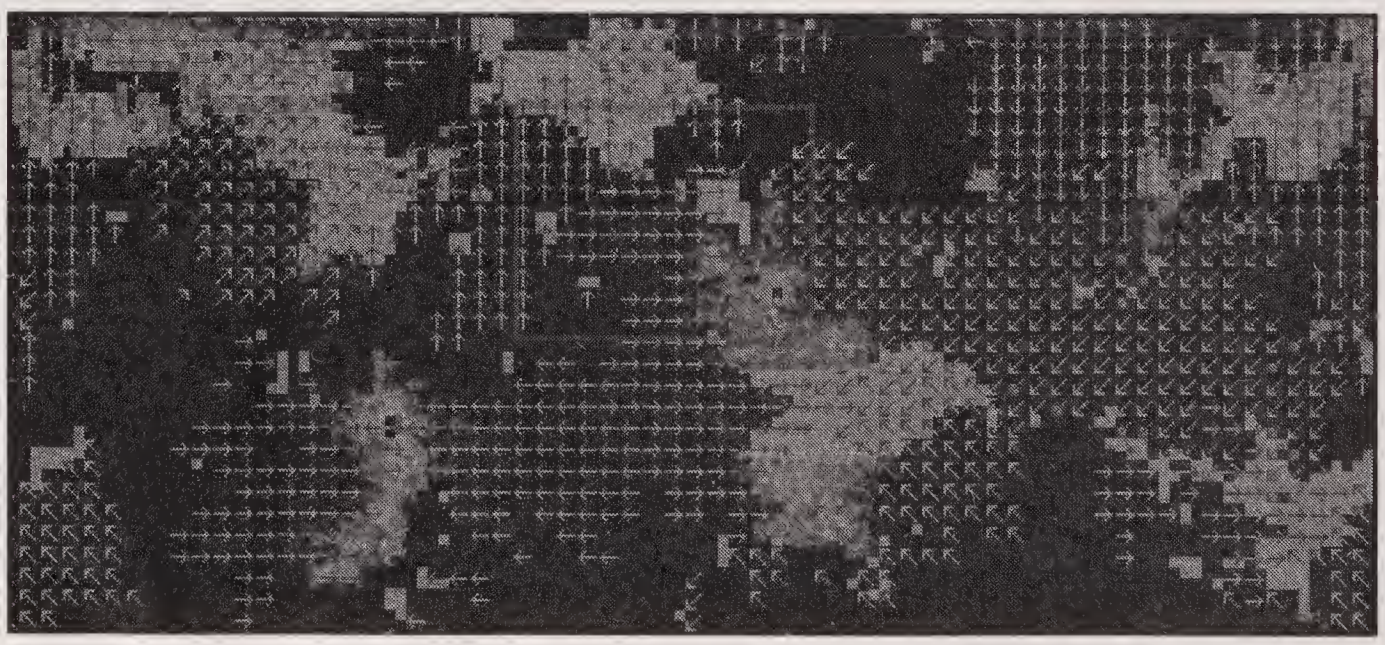
Over a long time, continents will grow from your tectonic meddling, and, if you've done a good job, you may be able to promote civilization on your world.



After a while the continents begin to form.



Here's the same planet using the Geologic map window.



Keep making more earthquakes, and you may end up with lots more land.

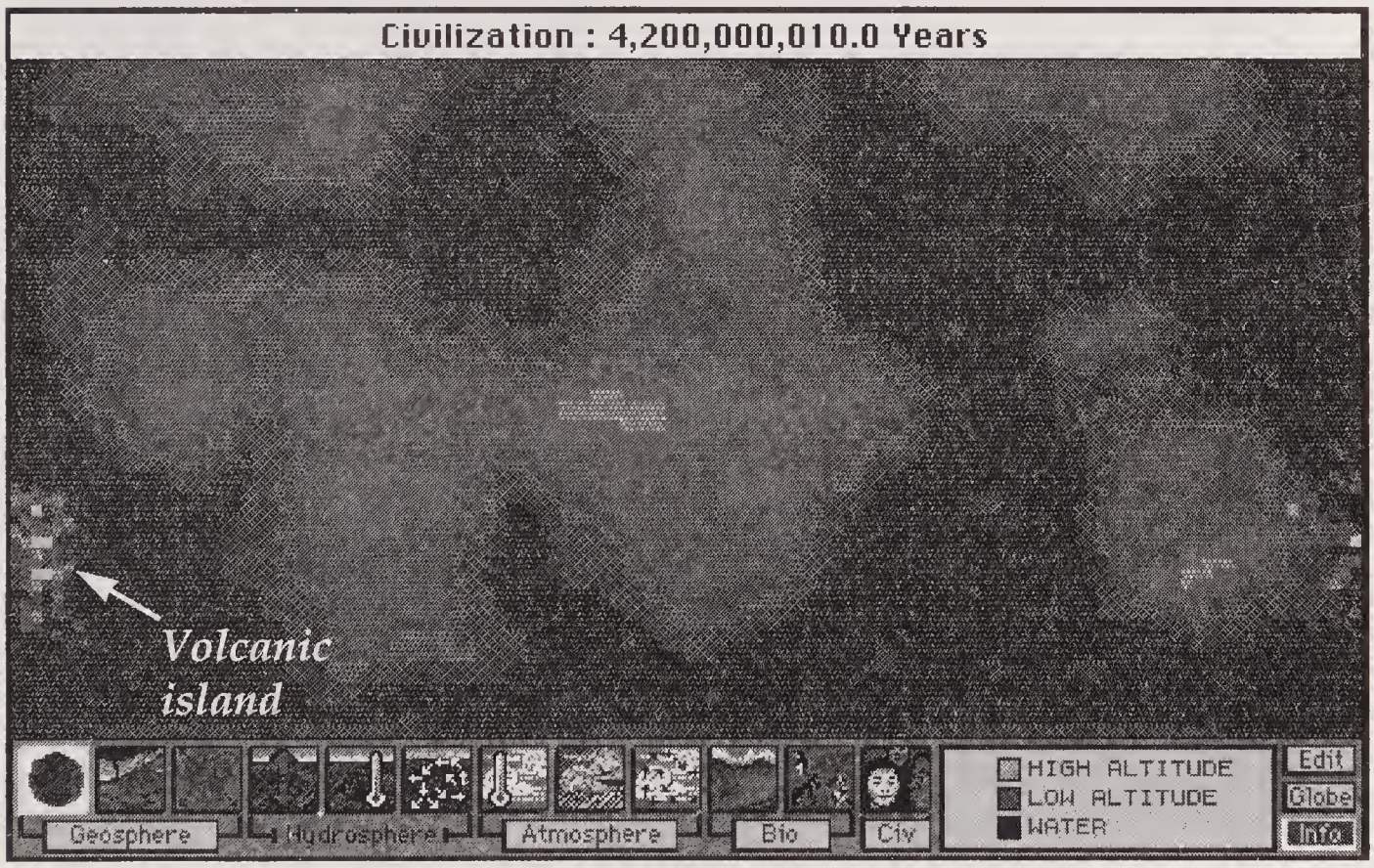
STAG NATION

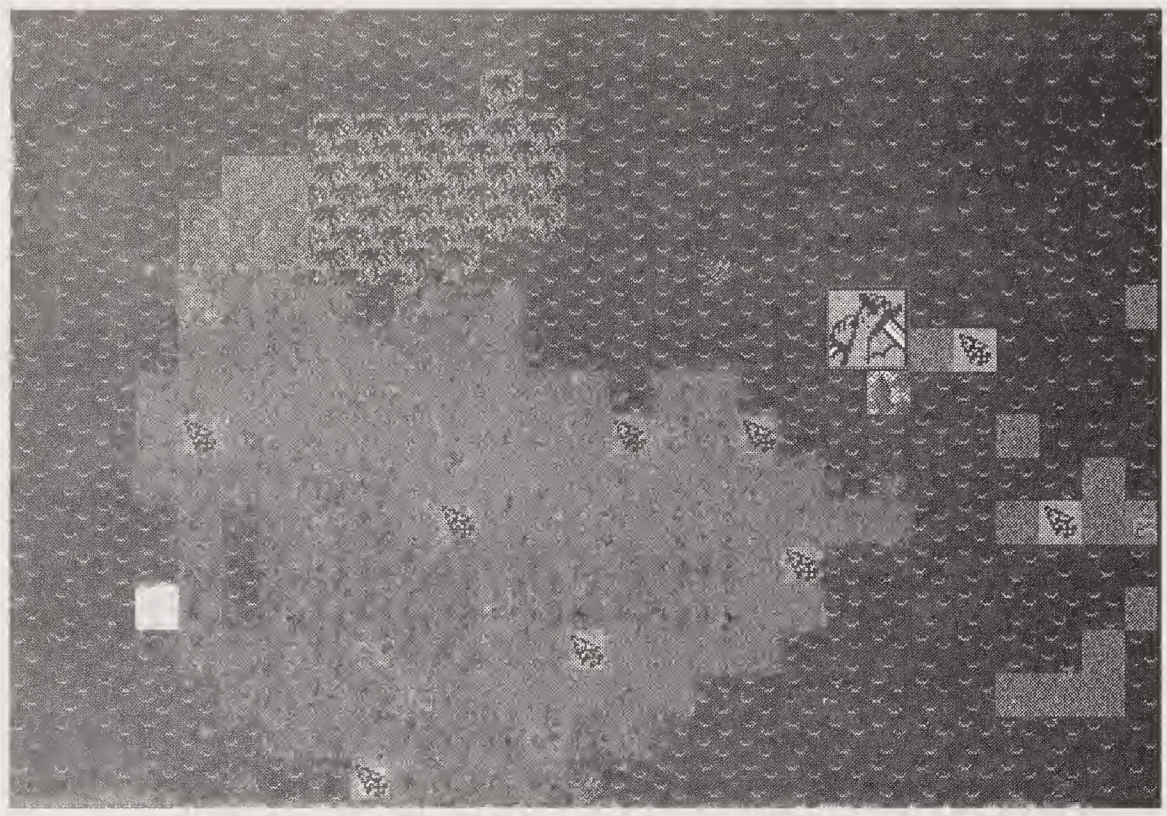
There are two ways to play this simulation—patient and impatient. If you're impatient, this one is pretty easy. If you can avoid the obvious solutions, you may find Stag Nation provides an interesting challenge.

In Stag Nation, you've got a Stone Age civilization trying to evolve on a relatively small island. There's a huge continent to the east of them, but they don't know about it and can't reach it anyway. There's a small island to the north, but it won't be enough room for them to expand. What can you do to help them get past this bottleneck?

The easy solutions are: 1) Build a land bridge using the Set Altitude tool. 2) Use the Moving tool to pick up a city and move it to the continent. 3) Use volcanoes to create new land. Or you can use a combination of these solutions for an easy fix. Of course, you could just wipe out this civilization and start over.

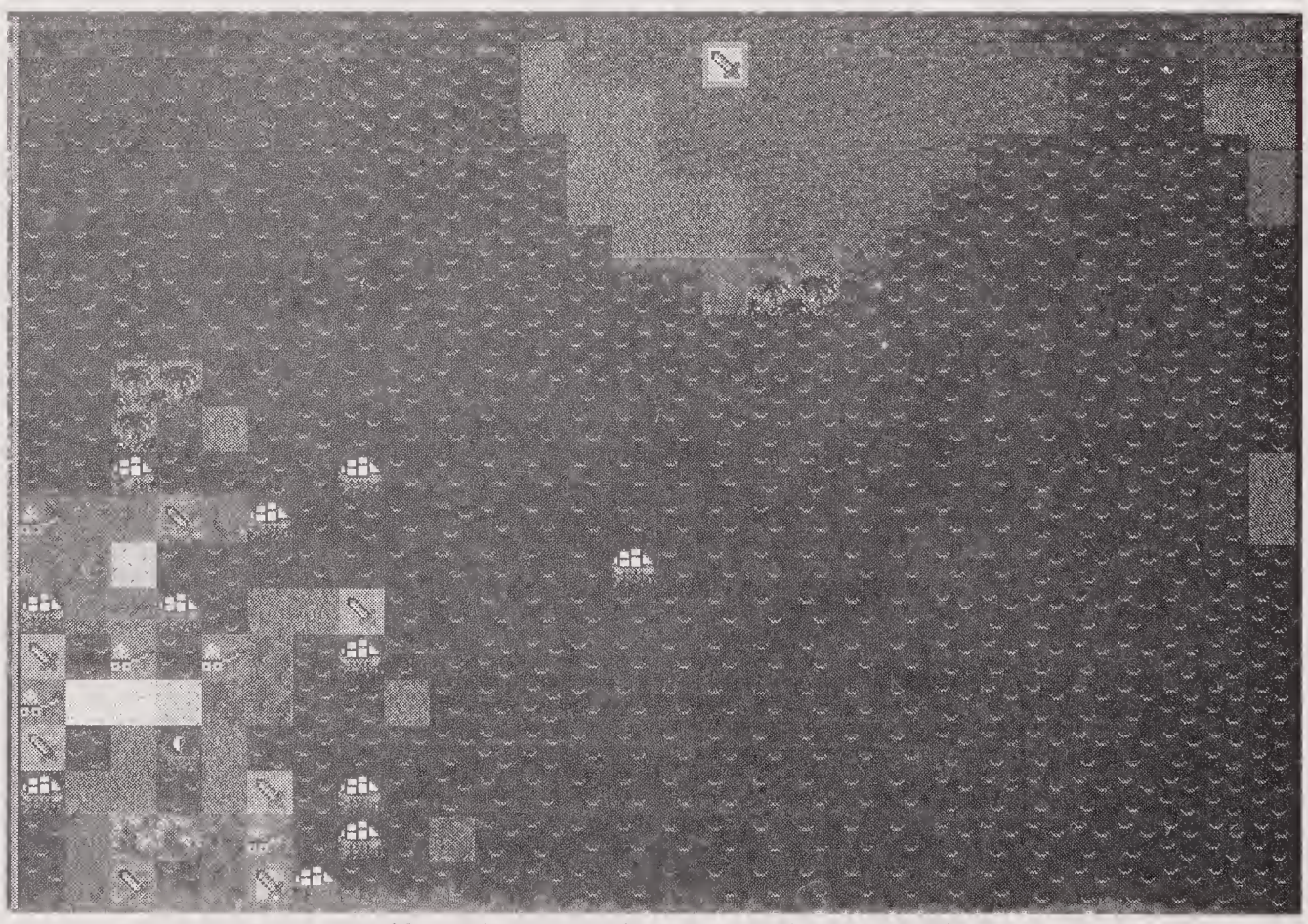
A slight variation on the volcano theme is more interesting, however. The trick is to set off just one volcano midway between the continent and the island. It may seem obvious to set one off west of the island, but you may want to consider placing a volcano to the northeast, near the island. In this location, the Stone Age wanderers should blunder onto the volcano's slopes eventually, and from there, it's a small step to the continent.





The Stagnoids finally discover the island.

You'll need to control the climate/atmosphere (which may become unstable periodically) and set the Civilization Model Control Panel to the formula that works so well: Agriculture first, Science second, Medicine third, and Philosophy and Art/Media last. This formula will keep your guys going while they bumble around. Eventually, if you can keep them going long enough, they'll advance to Bronze Age and beyond.



Eventually, they make it to the mainland.

It may take an infuriatingly long time for them to migrate to the volcano and then to the continent. It's almost as if the designers of SimEarth made these Stagnoids especially stupid and unobservant. At any rate, you'll definitely need patience to enjoy trying this minimal interference method, but you can succeed. Reaching the Bronze Age is an important milestone. The metal workers make better ships and get around better. They'll start to spread out much faster than the Stone guys did.

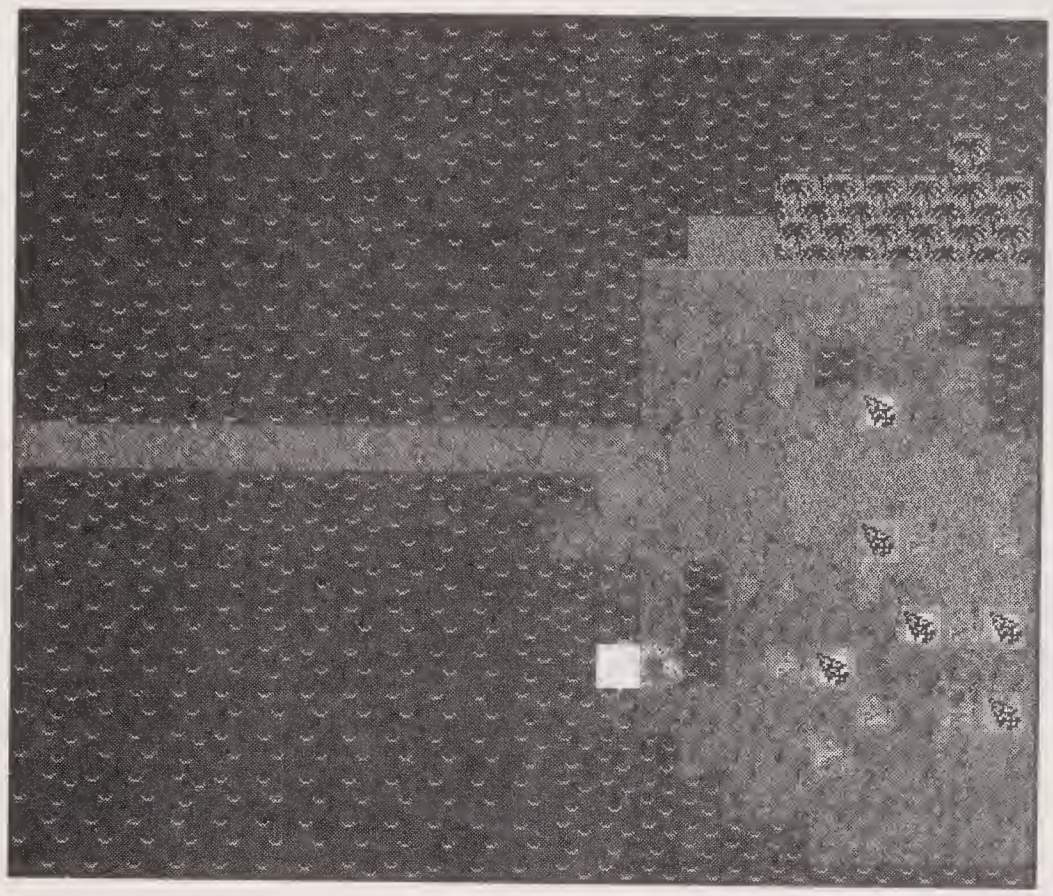
Probably only the Iron Age Stagnoids can make it to the continent, though. It all depends on where you place the volcano originally. If the gap between the volcano and the continent is still too long , try lowering the Greenhouse Effect or otherwise making the planet colder. If the ice caps grow, the sea level will fall and the land area grow. Possibly this will help your Stags bridge the gap. Eventually, once your civilization has settled on the continent, the scenario is just like any other.

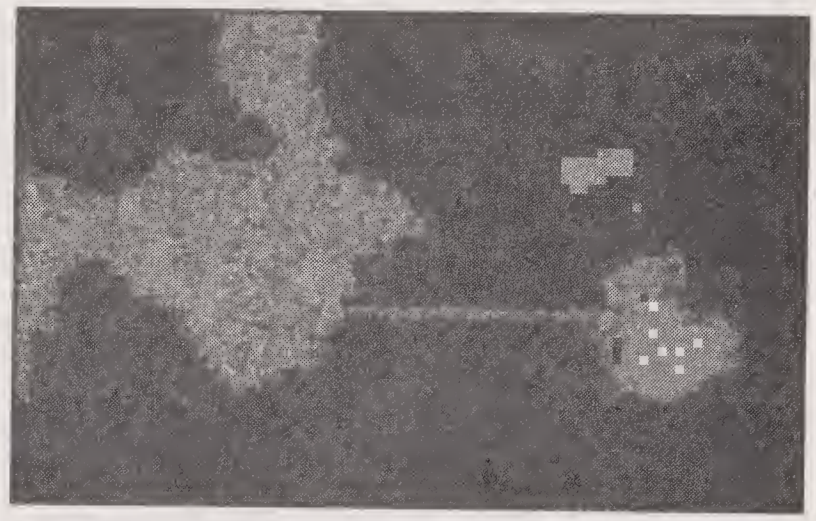
To reach Exodus, you'll need to continue to control the climate and the Civilization Model controls. Eventually, unless you build new land, your civilization will reach a peak level of population. Plagues can become a serious problem to continued population growth. You may need to balance Medicine against Science and Agriculture to maximize your population. You'll probably need to boost the Stagnoids' energy use once they've established the Nanotech Age by a sudden influx of fossil and nuclear fuels. But save these energy sources for the last push to the stars.

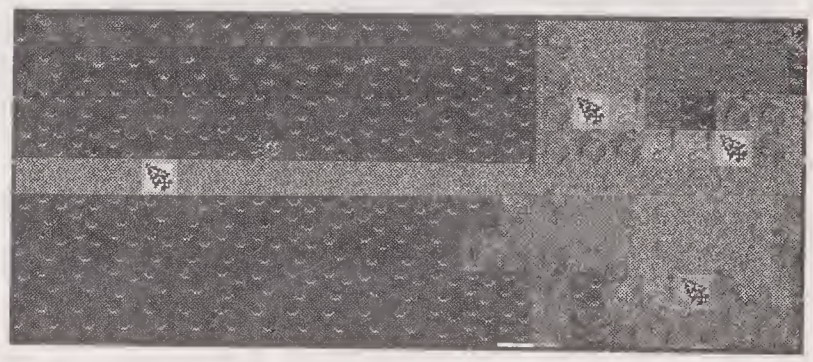
There are other interesting ways to play this game:

- Build a sort of one-lane highway between the island and the continent.
- Or build a series of small islands and try to lure the Sims over.
- Or kill off this civilization and return to the Evolutionary Time Scale where time moves faster, then use earthquakes and continental drift to create a new land mass between the island and the continent. (See Aquarium for how to do that.) Finally, wait for a new civilization to develop and use the new land.

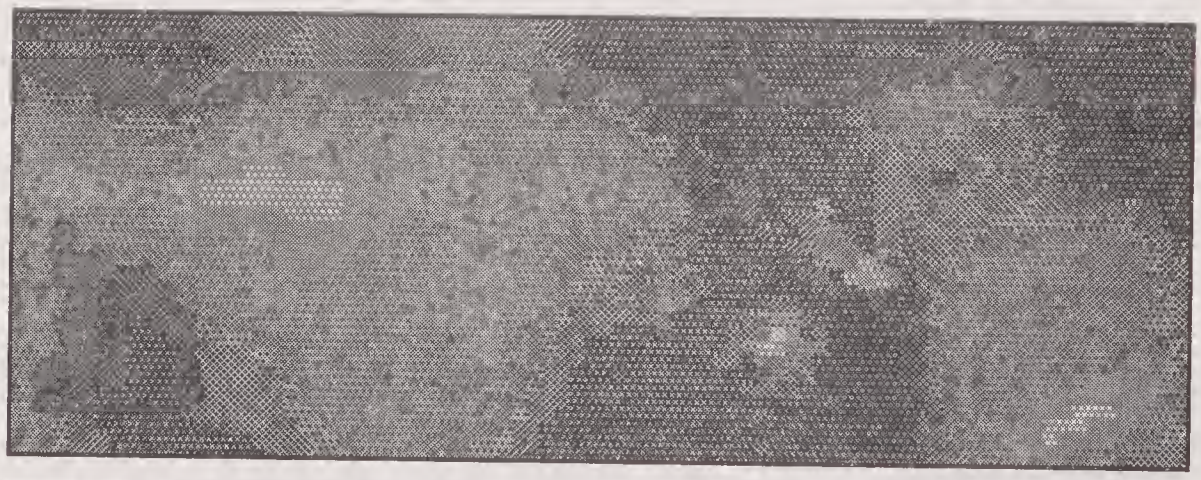
MORE STAG NATION IDEAS

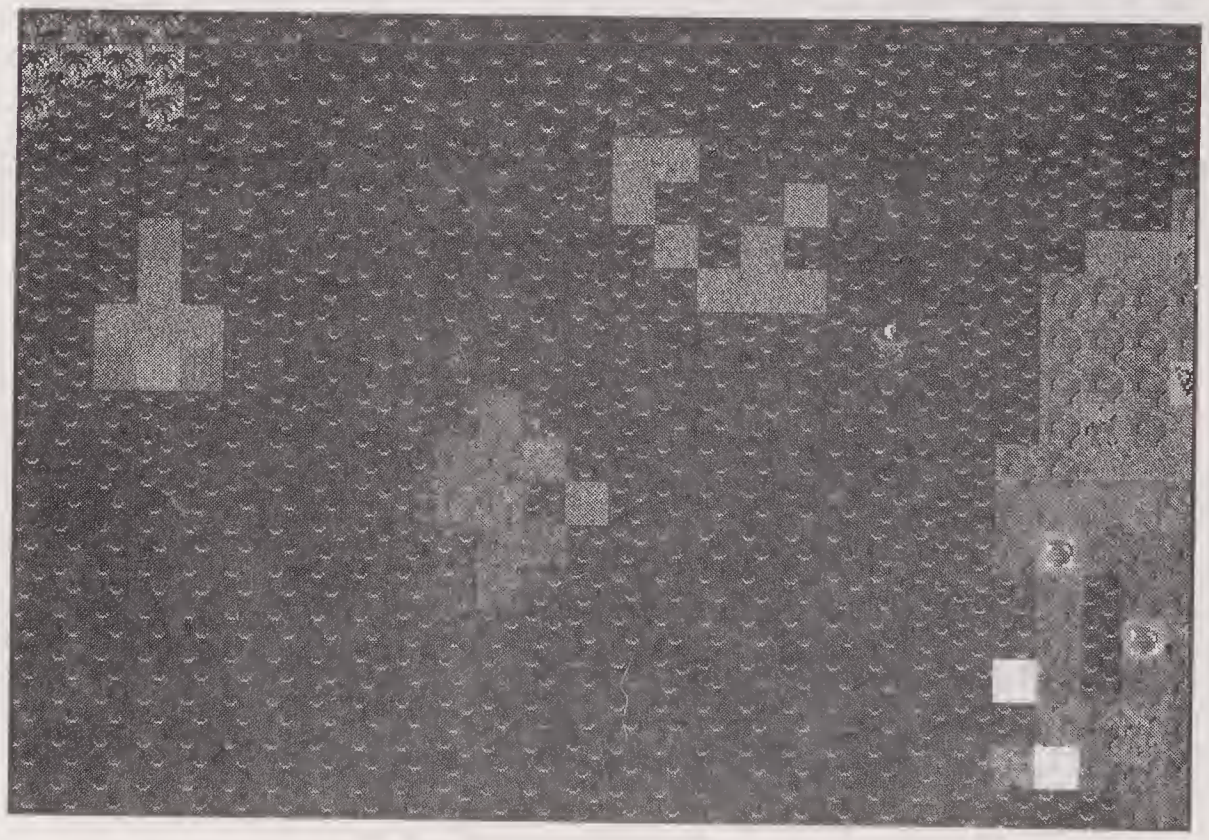






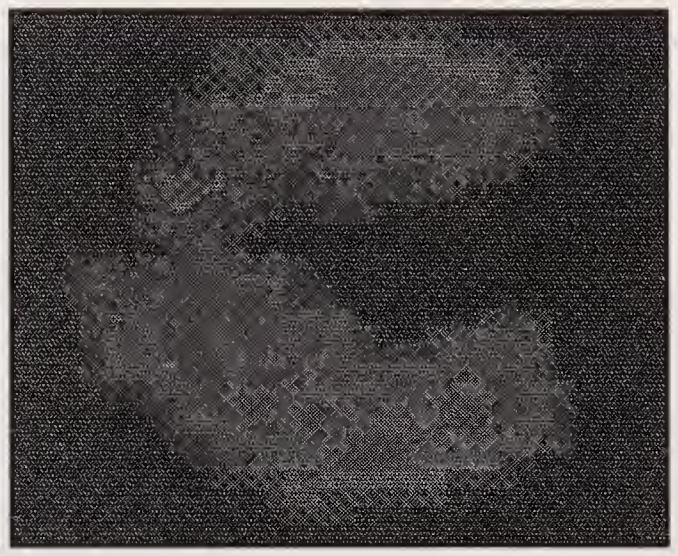
Above: The one-lane road doesn't get much traffic at first, but eventually the Stagnoids will find it. How long will it take?





The two lower pictures show the early island strategy. Again, it takes time and patience. Sometimes it seems that the Stagnoids do their best to avoid the islands.

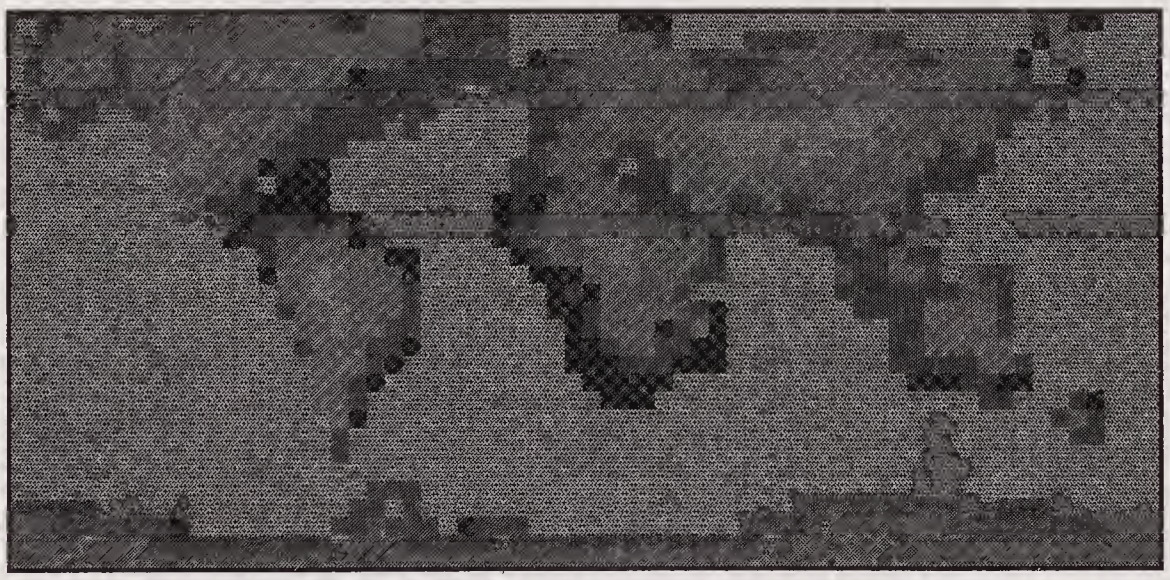
EARTH (THE CAMBRIAN ERA)



The Cambrian Earth scenario begins 550 million years ago when the continents of our planet were temporarily joined in the supercontinent called Pangaea (Pan = all; gaia = Earth). Life was spreading everywhere as plants and then animals invaded the land. The most interesting feature of this simulation is its modeling of the actual continental drift that split Pangaea into two pieces—Gondwanaland and Laurasia—and finally, following the best understanding of modern scientists, continues to form our present day continents. As much fun as it is to watch the continents drift, this scenario doesn't add much else that's new. If you've played the Random Planet scenario through the Evolution Time Scale, then you'll be pretty familiar with what happens here.

The charm of this particular scenario is that you can manipulate the evolution of life and eventually civilization on a model that will eventually look like the Earth we know. Otherwise, the same experiments apply to this scenario as do to the Random Planet scenarios.

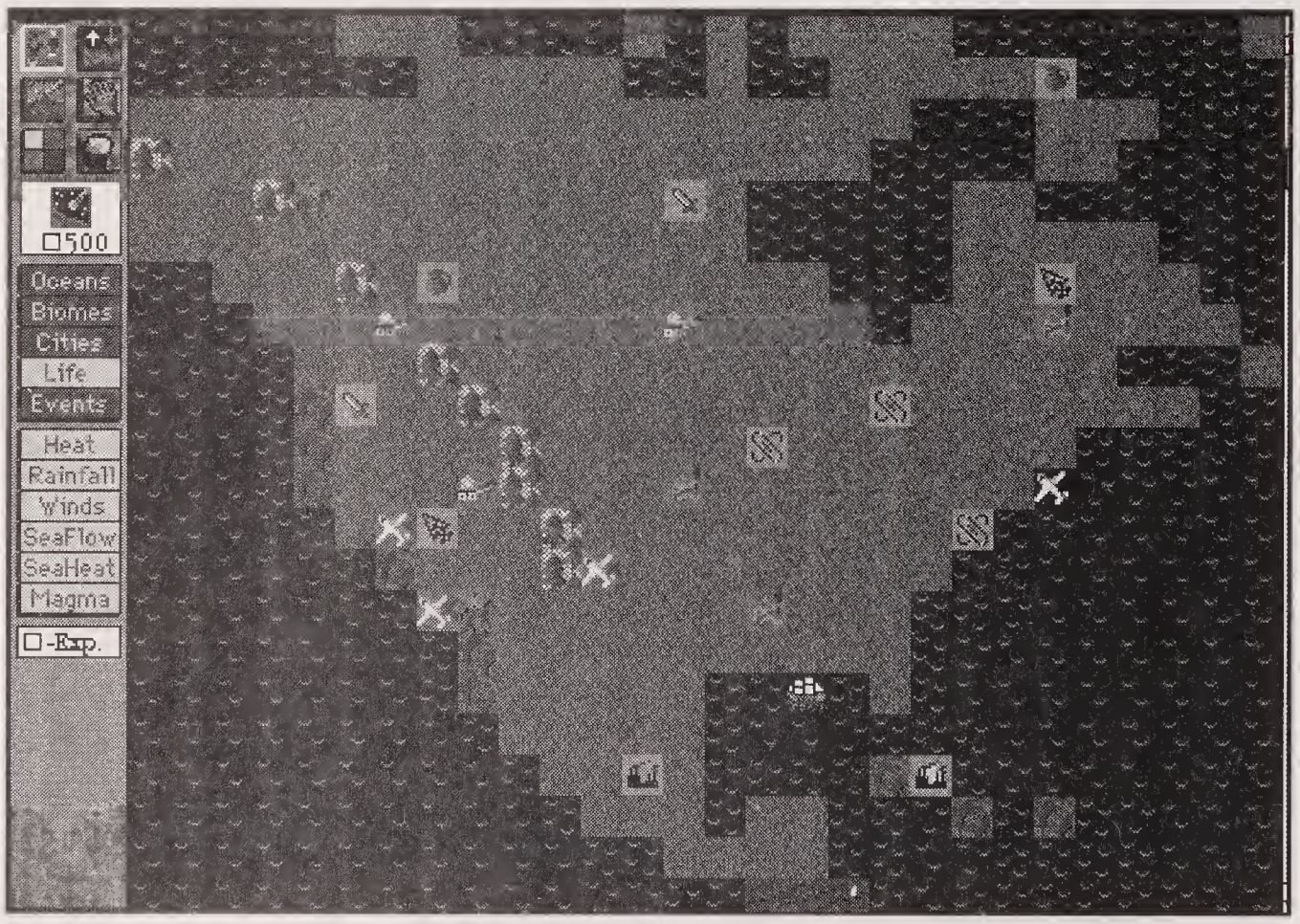
Of course, one other idea comes to mind. Using earthquakes, you can mess with the continental drift and perhaps try to reshape the continents to some other form. However, this scenario will tend to undo whatever you try. It's almost as if it has a mind of its own.



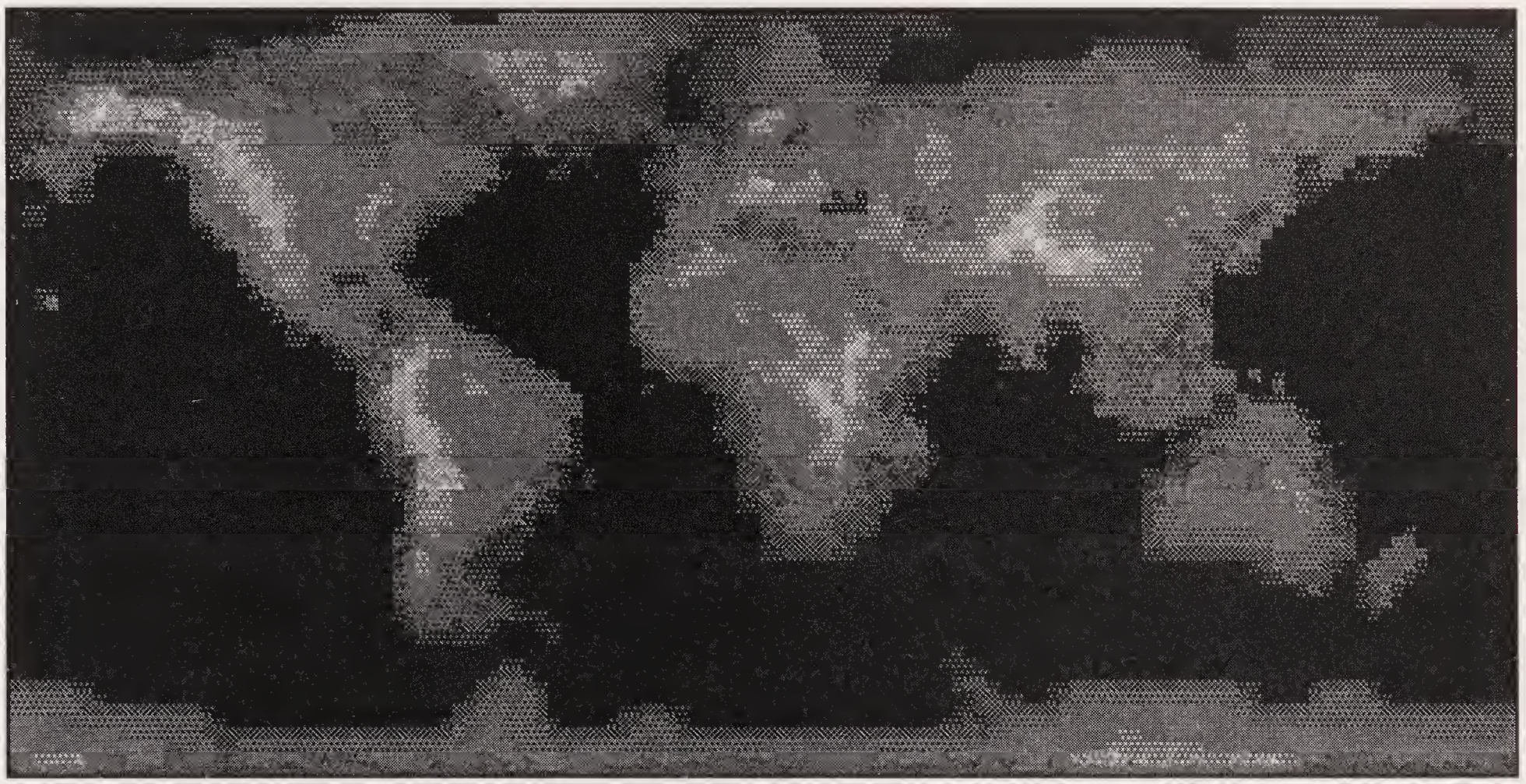
Events to watch for:

Soon after the biomes spread, CO_2 will fall. Great deserts will form. You can control this with the model settings. Try lowering CO_2 Absorption for instance. Or maybe mess around with Rainfall? Or maybe a hurricane in the middle of the continent?

"Tiger, Tiger burning bright..."
The United States from space as seen at night.



The SimEarth version.



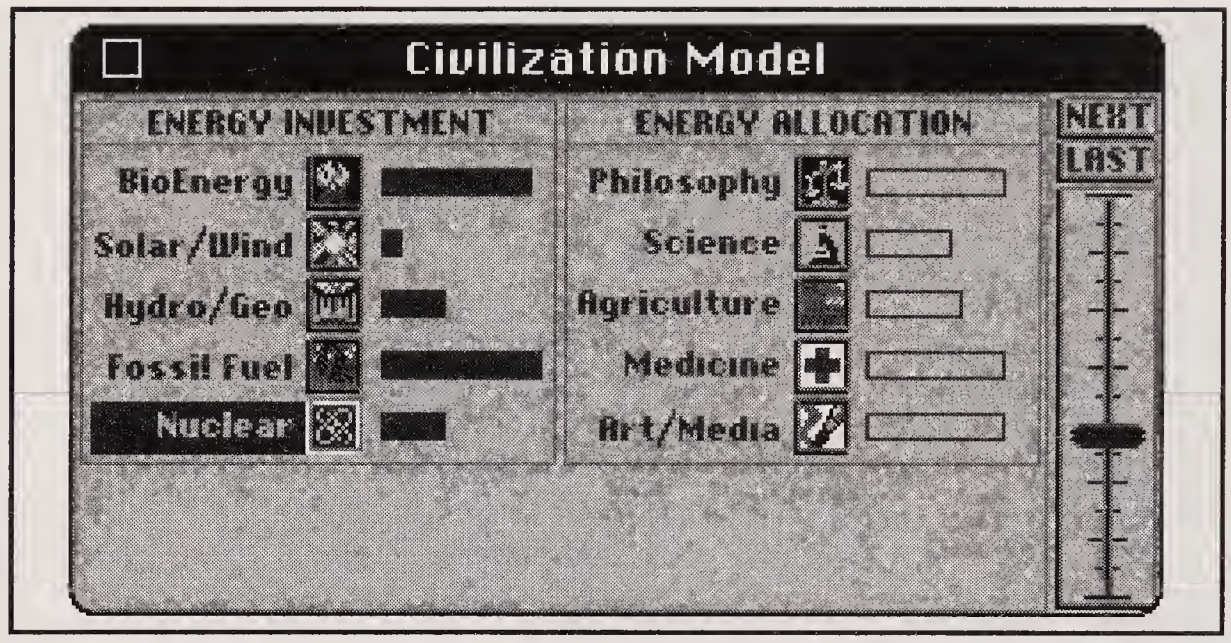
EARTH (MODERN DAY)

What can you say about this one? Of all the scenarios that come with SimEarth, this must be considered overly simplistic. First of all, it's very easy to bypass all the problems we really face, use various different energy formulas on the Civilization Control Panel, and get the Sims to Info Age, then Nanotech, and, finally to the Exodus.

It's a little harder to accomplish these goals while keeping the quality of life tolerable, or at least not "hellish." But you should be able to succeed even if you turn up Philosophy, Medicine, and, yes, even Arts/Media. You shouldn't have to use fossil fuels or nuclear energy until, possibly, just before Exodus. From time to time, you may have to respond to a change in the climate. You may also have to lower some energy allocation and raise Science to get to the next technological level. But it's pretty easy to get there.

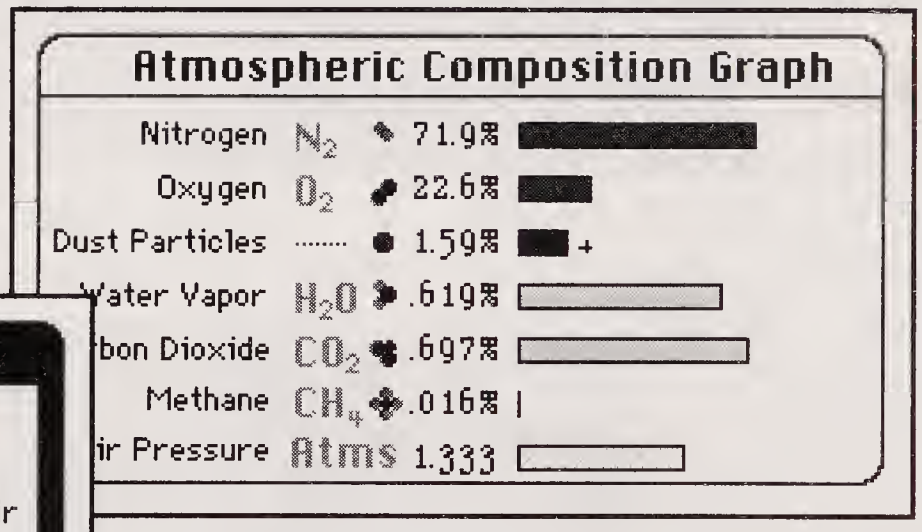
The scene is different, however, if you follow the current course of our civilization. The situation changes quite radically if you use fossil fuels and nuclear power. Then you'll find yourself taking the risks we face today—notably the risk of global warming as carbon dioxide levels rise, and the risk of nuclear war. Even though you can counteract the global warming by changing the Greenhouse Effect on the Atmosphere Model Control Panel, try seeing what happens if you don't.

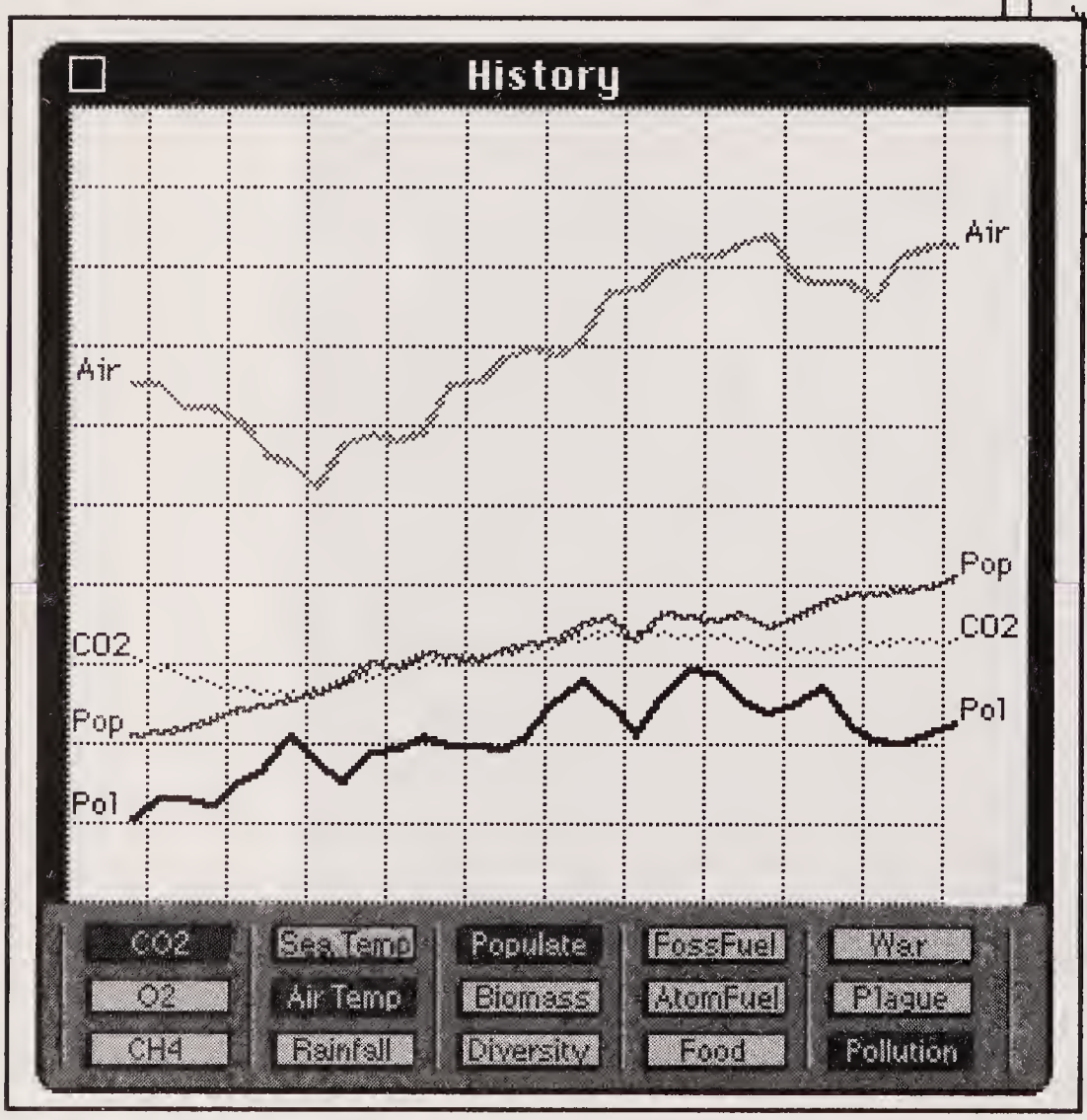
Early modern settings.



We tried a scenario that lasted for 100 years. In the first 50 years, we set the Civilization Control Panel settings as shown in the figure. We then let the Sims do their work, only raising the level of Science at around 40 years in response to a message from the Sims. You can see what was happening at

The story of the first 50 years of our experiment clearly shows a rise in carbon dioxide and a significant global warming. If we don't do something, we're cooked!

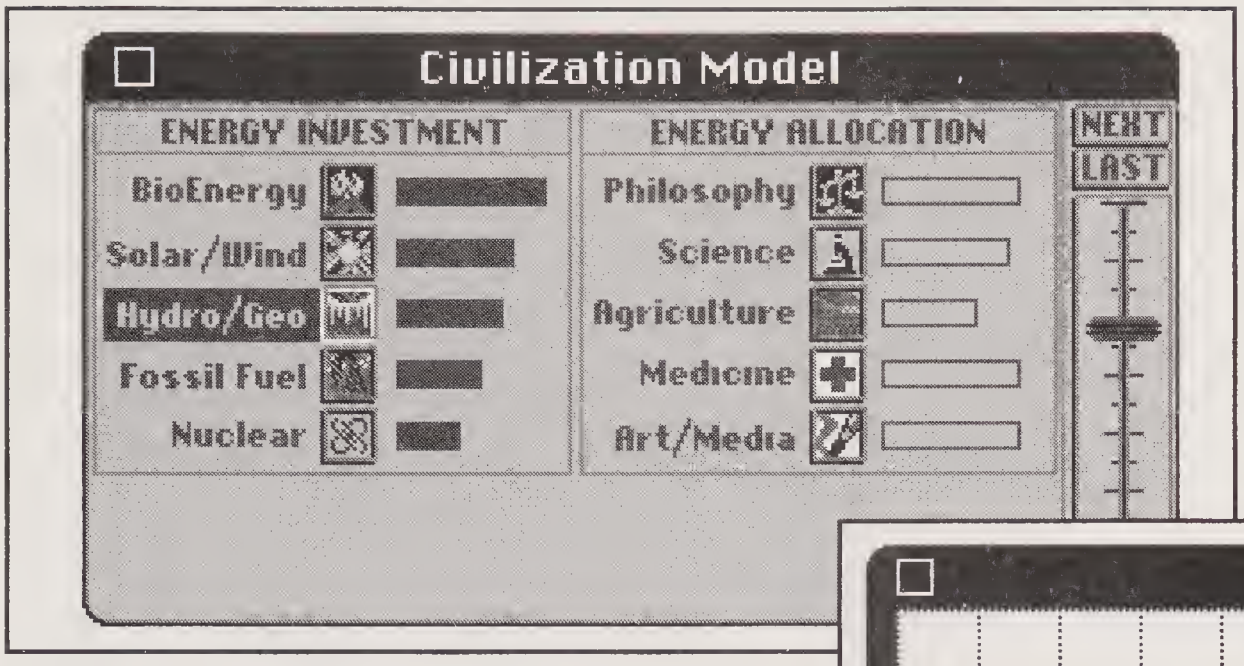




50 years. Carbon dioxide levels were more than twice what they are today, and the world had grown incredibly hot. If we were living on that planet now, we would be in deep kimchee as they say in Hawaii.

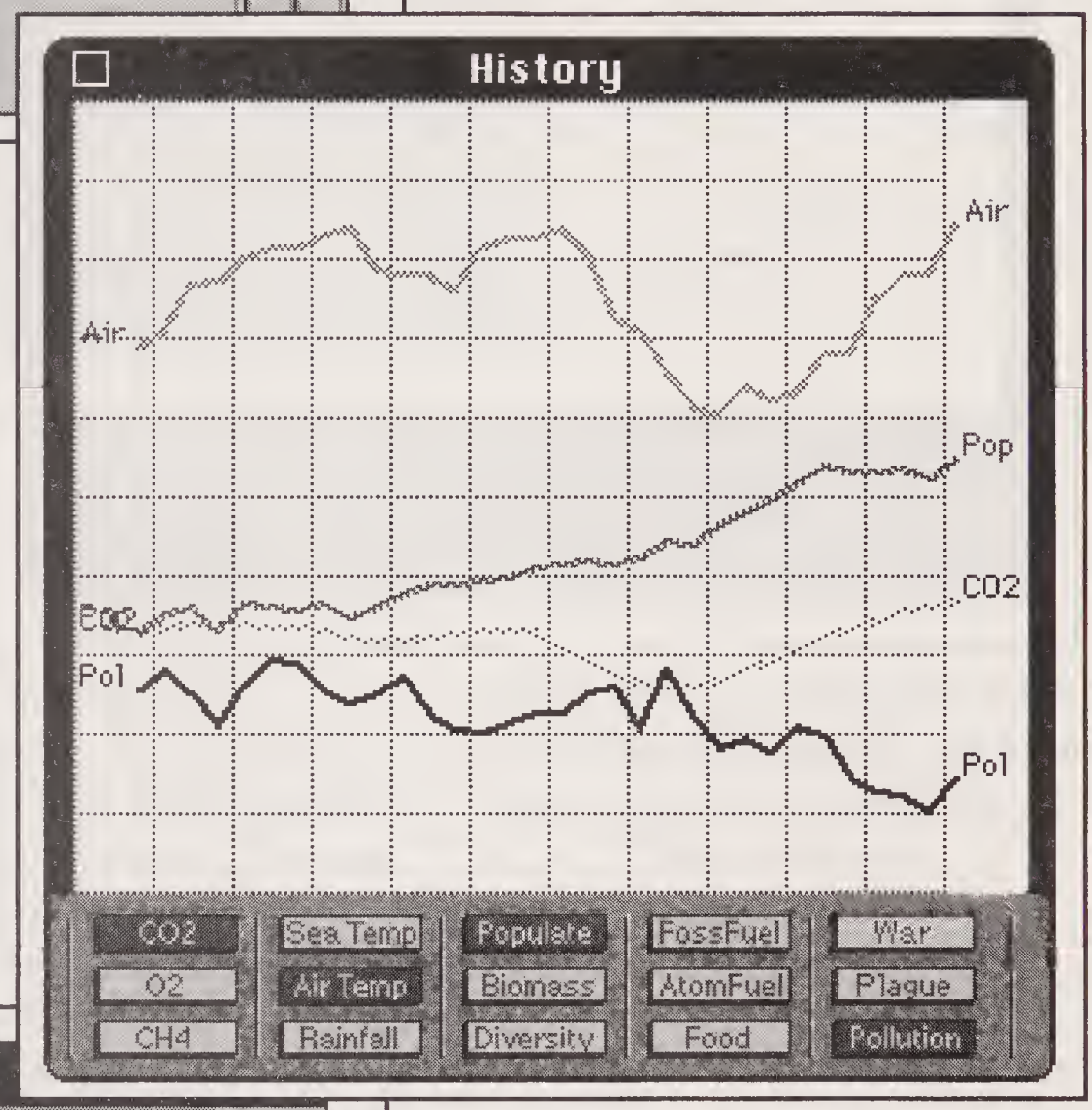
So we lowered Fossil Fuels by about half and raised our usage of other energy resources, leaving Nuclear about the same. The new settings are shown in the figure.

For the next 25 years, things started to improve, but by 75 years, CO_2 levels had risen even higher and things looked bad. Population

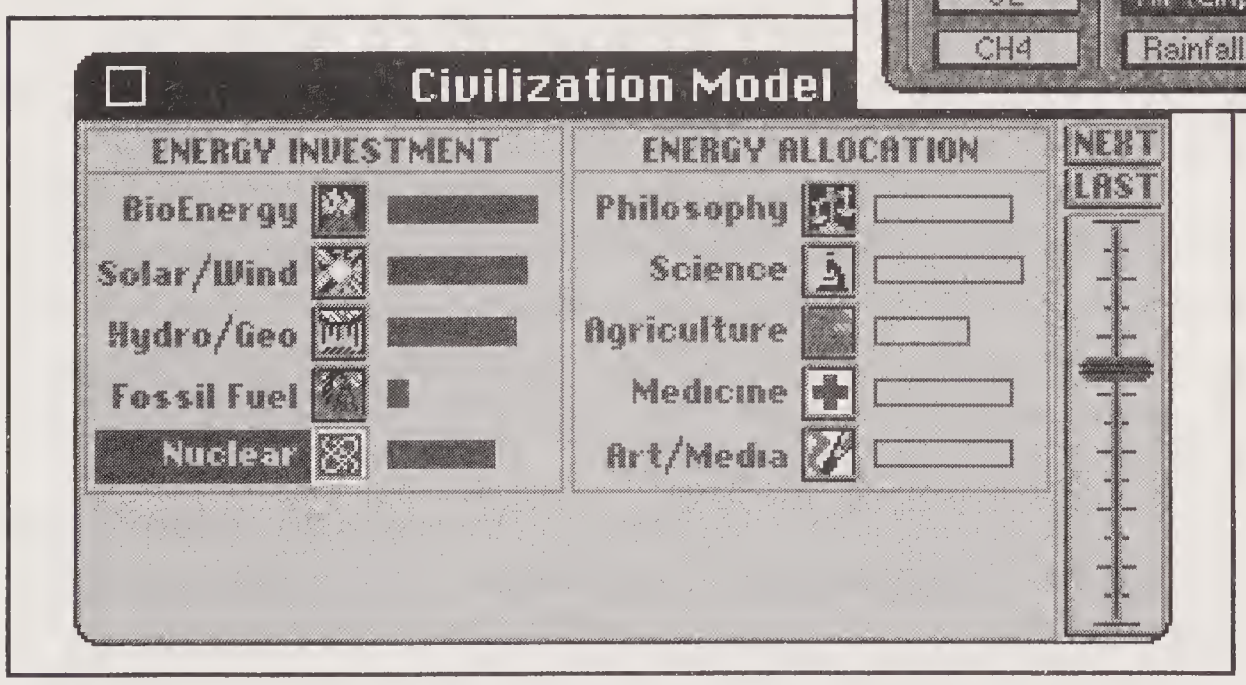


The 50-year tune up.

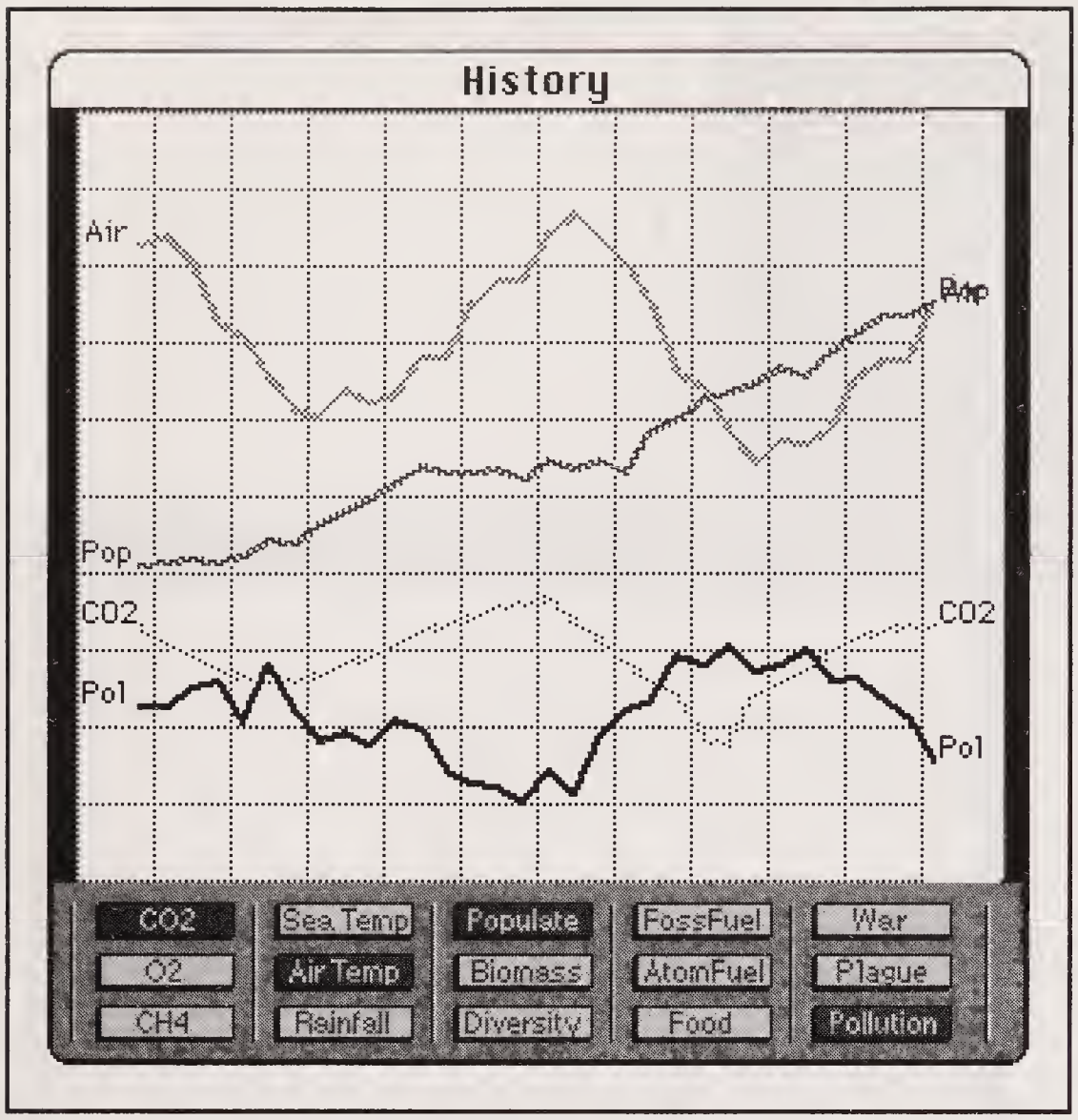
continued to rise although it is important to note that it began at about a tenth of our current population on Earth, and all estimates are that we'll be pushing 6 to 8 billion people in another fifty years or so... assuming no significant changes in birth rates and deaths from unanticipated events. So a population of just over a billion is nothing much for a Modern Earth scenario. Even so, you'll see that the global warming is significant, and what we consider daily life would be seriously disrupted if conditions were to reach that point.



The 75-year history, and it's still pretty bad.



At 75 years, we raised Nuclear on the hope that we would have discovered a safe source of power. Would we make it to 100 years?



After 100 years, we were pretty sure the Sims would lynch us if we showed up in town, so we made our exit.

For the next 25 years, we tried turning Fossil Fuels almost all the way down, raising other sources, and also raising Nuclear usage somewhat. Perhaps we'll discover a safe fusion technology.

By the time we reached 100 years in our test, population was still growing. Carbon dioxide levels were still high, but the situation had gotten somewhat better.

We decided to stop there. Do you think the Sims will make it out of the mess they're in? You can try for yourself. Perhaps, now that they're in the Info Age, they'll develop cleaner fuels, find solutions for their pollution buildup, and eventually reach the stars. Or perhaps they'll die on a steadily hotter planet as population grows and pollution keeps pace.

Of course it's easy to watch plagues and wars break out on your simulation and simply treat them as inconveniences or setbacks. The reality, as we all know, is much more brutal and cruel. When I play this scenario, I find myself becoming uncomfortable with these events. It's different when I play a scenario that I consider completely fictional or one that's set in the past where nothing I do will ever change the reality of events. I can't treat the Modern Earth scenario with such offhand indifference to events.

As we all know (especially after reading this book), the situation on Earth today is much more complicated than this model shows. There's no ozone hole, no deforestation model, no ocean fishing debacle. And even without all that, there's something to learn. The questions are hard to ask. And the answers are difficult to find.

In essence, the Modern Earth scenario is too much like all the other SimEarth scenarios, even if the map does look a lot like our own and you start out in the Atomic Age.

The Martian Landscape. Is that our next home?

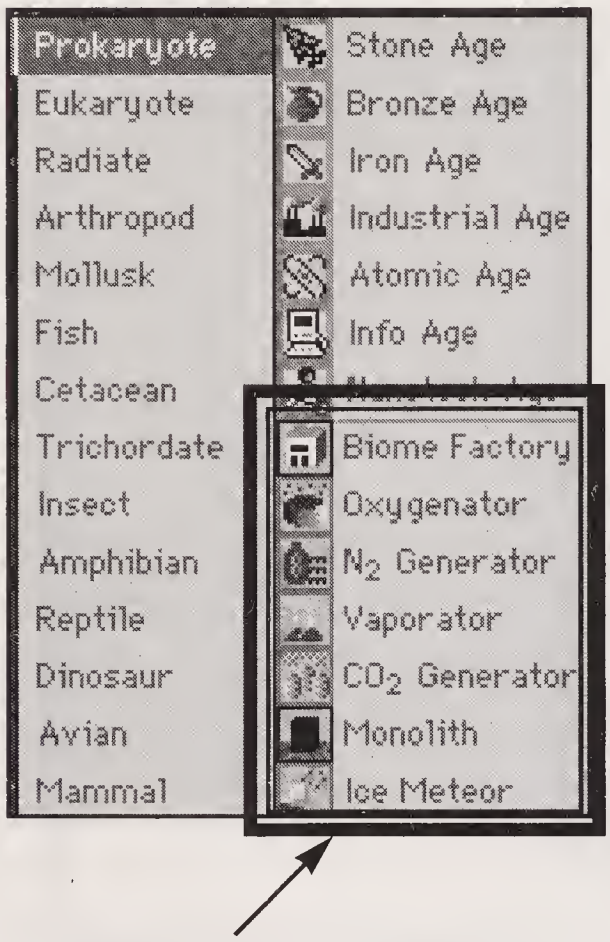
TERRAFORMING

Two of the simulations included with SimEarth involve terraforming other planets in the solar system—our closest neighbors: Mars and Venus. The job of terraforming a dead planet is not an easy one. There are major tasks, not the least of which is the complete recomposition of the atmosphere. There is also the need to bring temperatures within a range acceptable to life as we know it.

Our modern technologies would most likely be inadequate to do jobs on this scale, but future technologies may provide us the tools to accomplish such truly Herculean tasks. So, in SimEarth, you are provided with an assortment of ultra-high-tech gizmos that make your job, if not easy, at least possible. These devices, the terraforming tools, are the important keys to success. We looked at them in the reference section of this book, but let's take a closer look now:

The Biome Factory

The Biome Factory performs some rather complex analysis of its environment and then manufactures an appropriate biome for the current climate conditions. Once an appropriate biome is created, it tends to spread out on its own. In the meantime, the biome factory will keep working tirelessly to make sure its surroundings are as suitable as possible for given conditions.



The terraforming tools.

The Biome Factory costs 500 EU, and, in a limited energy scenario, that can be expensive. Therefore, the best way to use the Biome Factory is to place in a location to get appropriate biome growth started, then use the Mover Tool to relocate the Biome Factory. Keep moving it around until your planet is covered with biomes.

The Oxygenator

Oxygen! That reactive poison that's so necessary to our way of life. It corrodes and burns and can destroy quickly if not held in check, and yet our planet has kept oxygen levels at a safe, relatively stable level for millions of years.

On Mars and Venus, oxygen does not exist freely in the atmosphere, and the Oxygenator is one of the tools you can use to pump more free oxygen into the air.

On Venus, the Oxygenator is one of your most important early tools. Use it to replace carbon dioxide and eliminate the heat build-up caused by the greenhouse effect. Only then can Venus become a suitable home for our kind of life.

The N2 Generator

Nitrogen is a necessary, if inert, component of our atmosphere, comprising more than 70% of the air we breathe. Among other things, nitrogen helps keep things from burning up. If oxygen levels were to rise above 25%, even wet plants would burn up! Nitrogen also acts to increase atmospheric pressure, which effectively increases the greenhouse effects of such gases as carbon dioxide and methane. Like the others, the N_2 Generator is 500 EU.

The Vaporator

The existence of great bodies of water on a planet increase the volume of water vapor in the air, which, in turn, increases rainfall and biome growth. However, sometimes you can stimulate growth with a well placed vaporator or two.

The CO_2 Generator

One of the main problems you'll have when terraforming Mars and Venus is the level of carbon dioxide. On Mars there's too little and the planet is frozen. On Venus there's too much and the planet is a hellish steam bath. Needless to say, you shouldn't need to use the Carbon Dioxide Generator on Venus, but on Mars it can come in quite handy. It costs 500 EU.

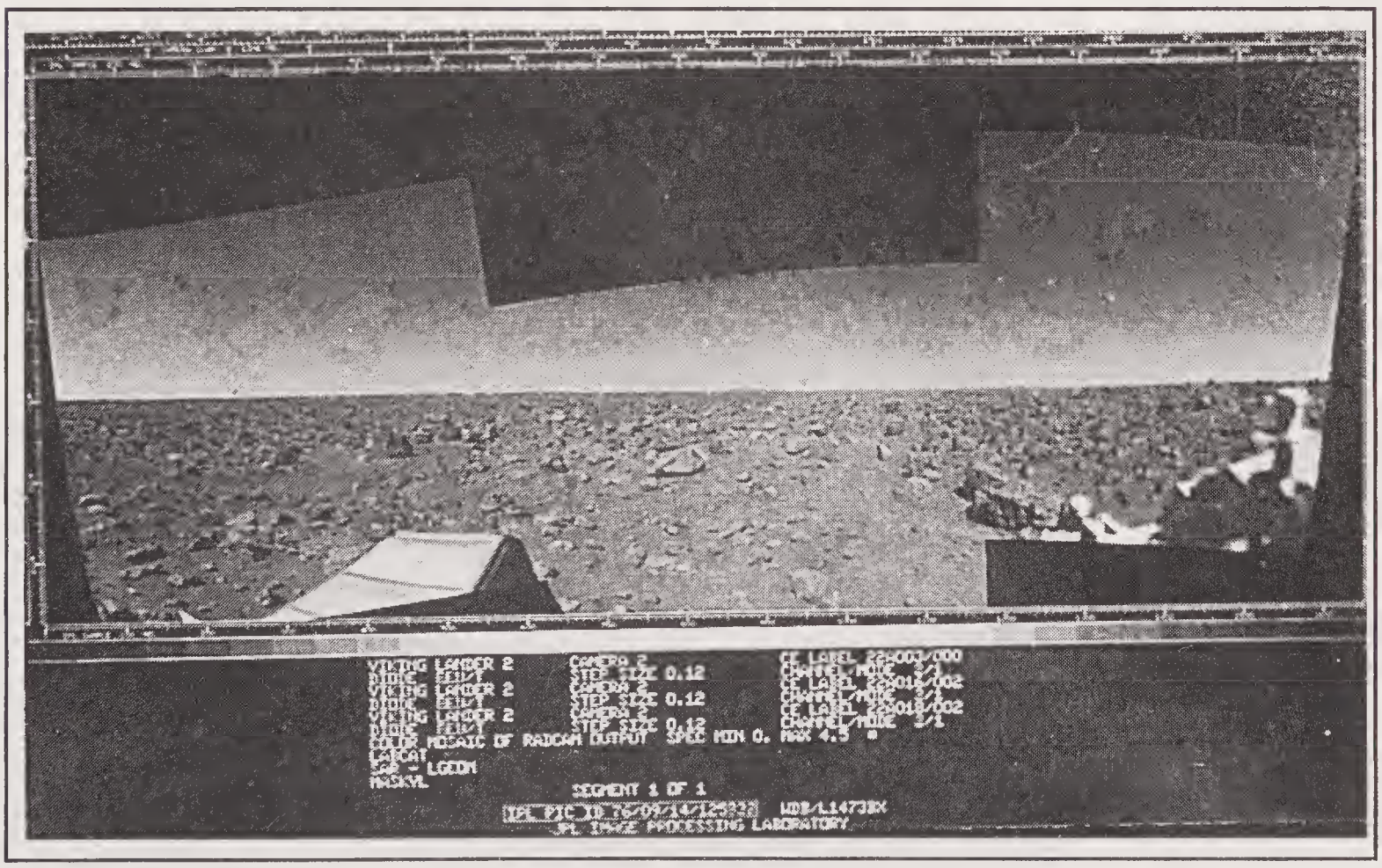
The Monolith

Although it is certainly the most high-tech of the nanotech toys in SimEarth, the Monolith is really not much needed in the terraforming simulations. It can cause creatures to leap ahead along the evolutionary path, but it is presumed that the terraforming missions are already headed by intelligent mammals and so it shouldn't be necessary to try to advance anyone else.

The Ice Meteor

The Ice Meteor is a very effective way to provide water for a dry planet. On the Macintosh, the Ice Meteor is only 500 EU, so it is possible to drop two or three, even in one of the limited energy modes. However, at 1000 EU, IBM PC compatible users will have to be more frugal. If you're short on EU, drop one Ice Meteor and then use the Set Altitude tool to create ocean beds. Once there is free water on the planet, it will fill available spaces at or below its level. So one Ice Meteor may suffice to create a whole ocean.

In our experience, however, the IBM version of SimEarth seems to need more ice meteors than the Mac version to get a good ocean started. You'll see this later as we begin to terraform Mars and Venus.



Taking a first survey of Mars. Getting ready for the big project!

MARS

The Red Planet, Mars, is a frozen wasteland. Its atmosphere is thin and inhospitable with a predominance of carbon dioxide and almost no free oxygen. Liquid water is unknown on the surface of the planet, though some scientists believe there may be ice somewhere beneath the surface.

Mars—The Easy Mode

Terraforming Mars in the Easy mode of play is no big problem. The key difficulty lies in the very low temperature of the planet and its lack of water. Another major obstacle is the extremely low air pressure which is not sufficient to trap water or to allow any greenhouse effect to warm the air. Therefore, the first action you should take is to begin to increase the air pressure with CO_2 and N_2 Generators.

Warning: The approach taken in this section will allow you to terraform Mars in record time. However, there is no guarantee that the resulting planet will be stable. It may be subject to wild fluctuations of atmospheric gases and pressure. For a more stable planet, take more time, place more gas generators, and build up the atmospheric pressure before forming oceans and following the rest of the steps. We'll remind you of your options at key points during the runthrough that follows.

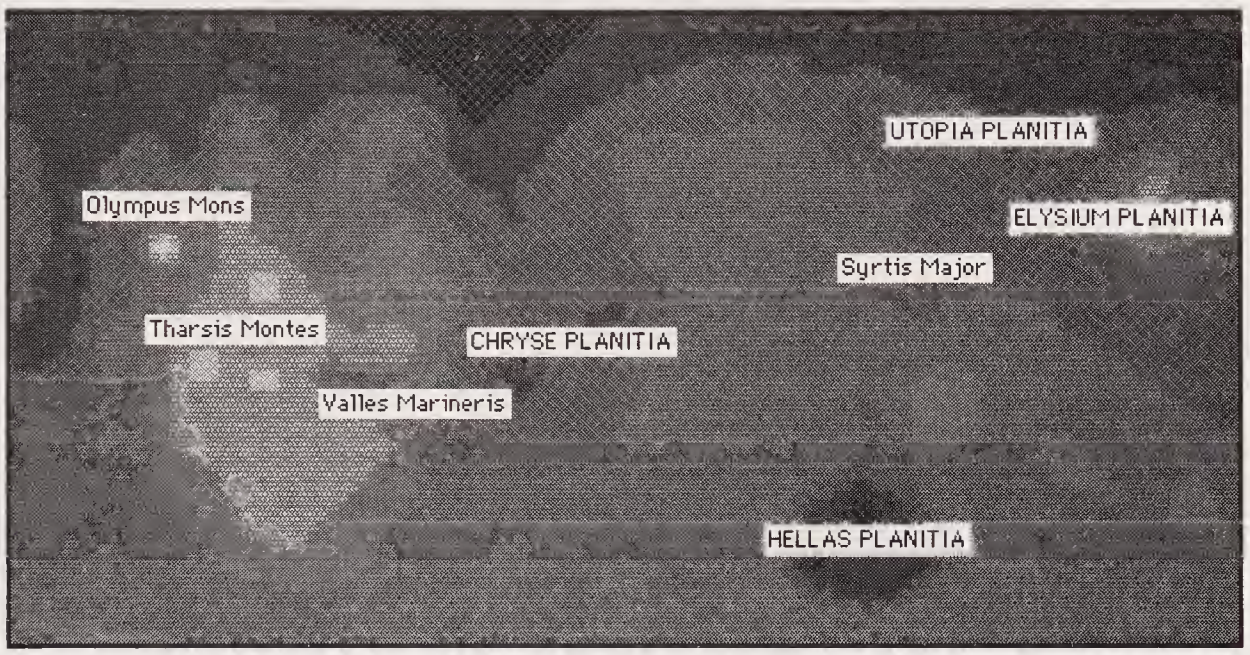
1. **Select New Planet from the File menu and select Mars in the Easy Mode.**

2. **Pause the simulation.**

3. **If you have the room, open the Air Sample graph, the History window, the Report window, and, of course, the Edit window.**

4. **Examine the Report window to see what your goals are: Biomass, 25,000; Population, 1,000 million.**

If you don't have room on your screen to show all these windows at once, be prepared to display them from time to time in order to monitor what's going on. In particular, you'll need to keep an eye on the History window and the Air Sample graph (also known as the Atmospheric Composition Graph).

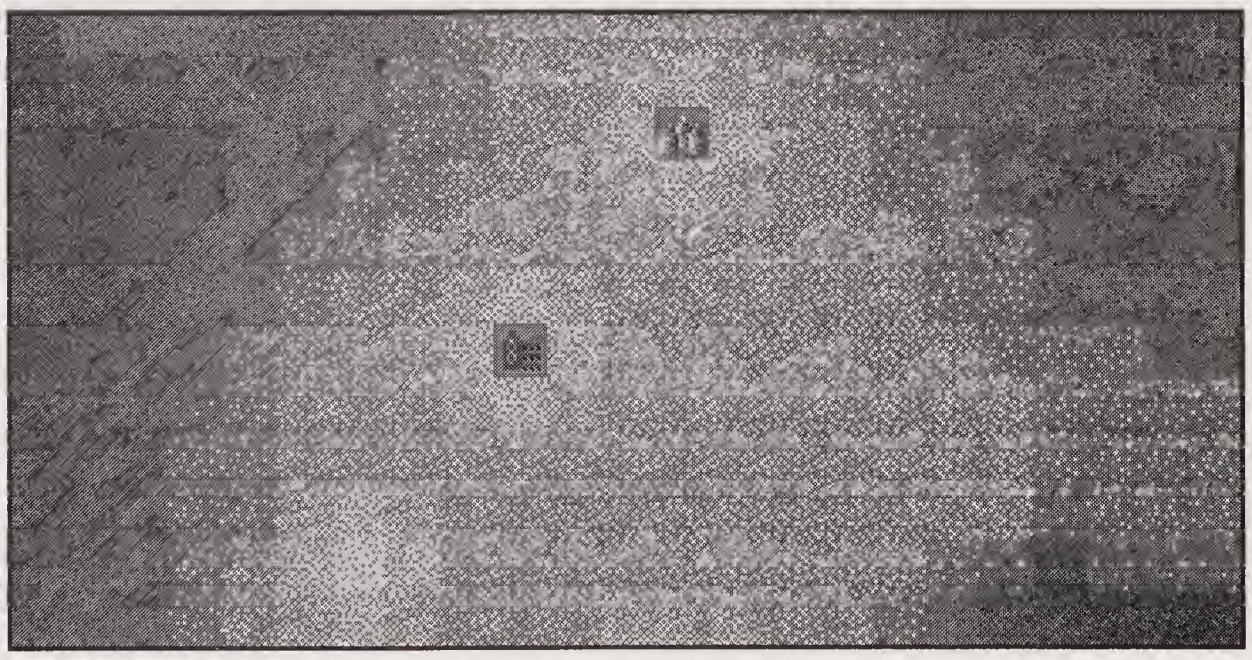


Composite of images from the Tharsis region.

5. **Find the Tharsis Montes (press and hold on the Terrain Map icon in the Map window).**

6. **Place a CO_2 Generator at the top of the mountain.**

7. **Place an N_2 Generator near the CO_2 Generator.**



For a more stable planet, you would place several CO_2 Generators and one N_2 Generator, then wait at least fifty years before forming oceans. However, in this super-fast approach, you can actually form the oceans between five and ten sim-years. Other than the time it takes to complete the job, and the amount of instability on your planet, the steps will be pretty much the same.

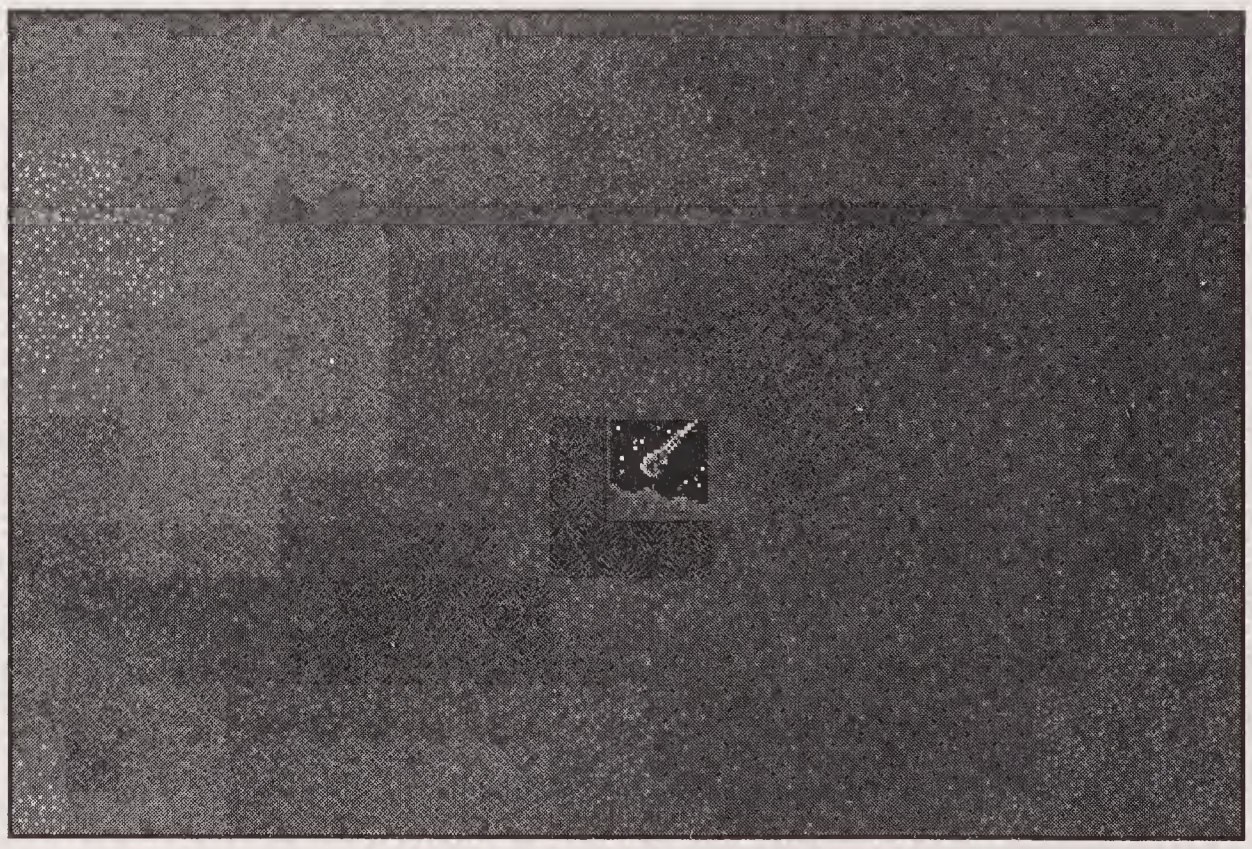
8. Restart (unPause) the simulation.

You may want to use the Slow speed to allow time to see what's happening. Watch the air temperature in the History window and the air pressure in the Air Sample graph.

The air temperature should rise somewhat, but it will remain cold. After a while, though, you'll want to form some oceans, and there's nothing like an ice meteor to do it.

9. Find the Chryse Planitia, a deep valley in the surface of Mars, just east of the Tharsis Montes.

10. Now select Ice Meteor from the Place Life palette and drop one in the middle of the Chryse Planitia valley.



You may need to drop another ice meteor. You'll know if one ice meteor is enough because all the deeper valleys on Mars should show water after you drop it. If you don't see water in various locations on the planet, drop another ice meteor.

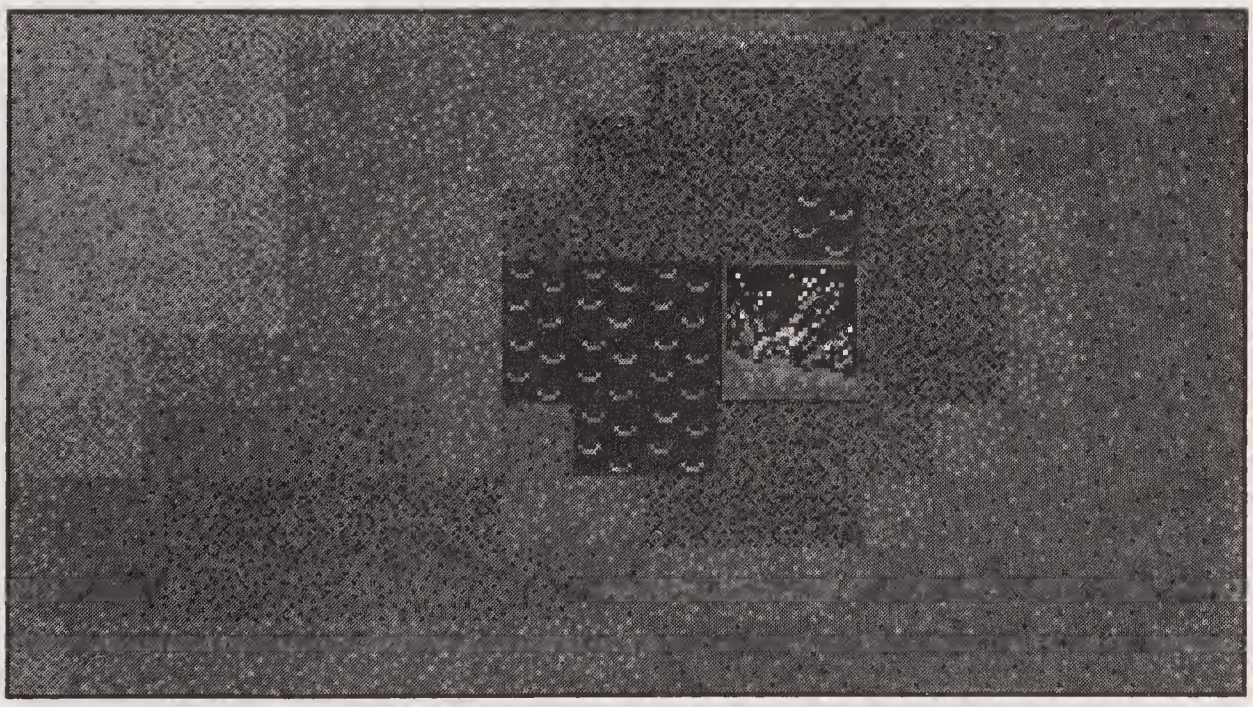
11. (optional) If you need to do so, drop a second Ice Meteor.

Now that you have small oceans, you'll use the Set Altitude tool to expand the ocean area.

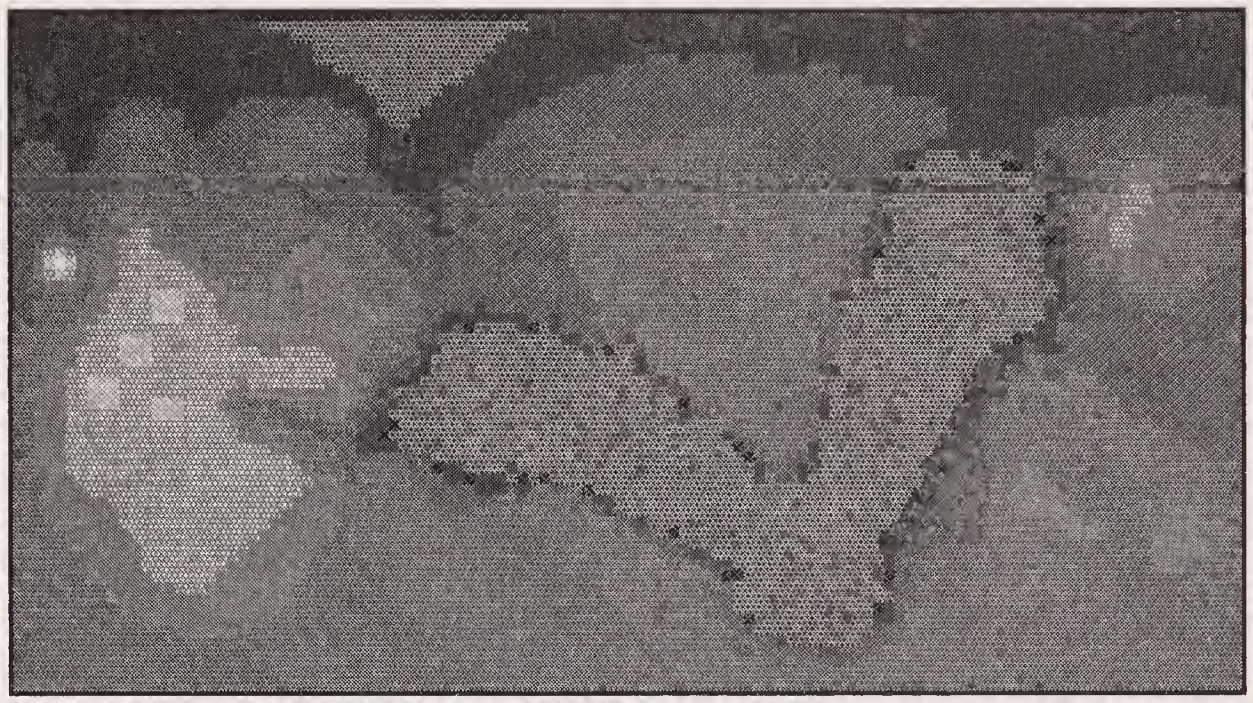
12. Select the Set Altitude tool from the Edit window and be sure the arrow is pointing down.

13. Begin to lower the land around the lake you formed in the Chryse Plantitia.

Keep lowering land, moving eastward, until you have dug out a fairly good sized ocean. On the Macintosh, the water will appear wherever you lower the land sufficiently. On the IBM version, you won't see water where you dig, so just dig deep. How much land you carve out is up to you. Just remember, if you keep digging and don't release the



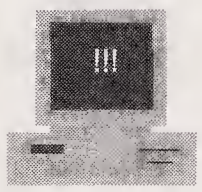
Sometimes water forms right away.



A small ocean.

button, you will only spend 50 EU for the whole excavation process. Also, no time will pass while you're excavating. (You must have one heck of an earth moving machine!) Once you have carved out an ocean, release the button and view the results.

On the IBM version, when you finish digging, your ocean will probably remain dry. If it does, you'll need to drop one more ice meteor.



13a. (IBM only) If your oceans are dry after you dig them out, drop a third ice meteor somewhere in the ocean basin. This time it should fill up.

14. The oceans may freeze up right away, but if you find an area that remains liquid, drop a Eukaryote in it to start generating some oxygen.

Don't worry if strange events occur. For instance, your oceans may completely disappear. Don't panic. They'll be back momentarily. We don't know what happens to them, but they do return. Our best guess is that the air

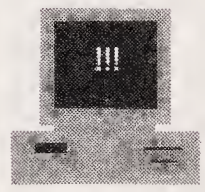
pressure is too low and they vaporize. Fortunately, as air pressure rises, they should come back.

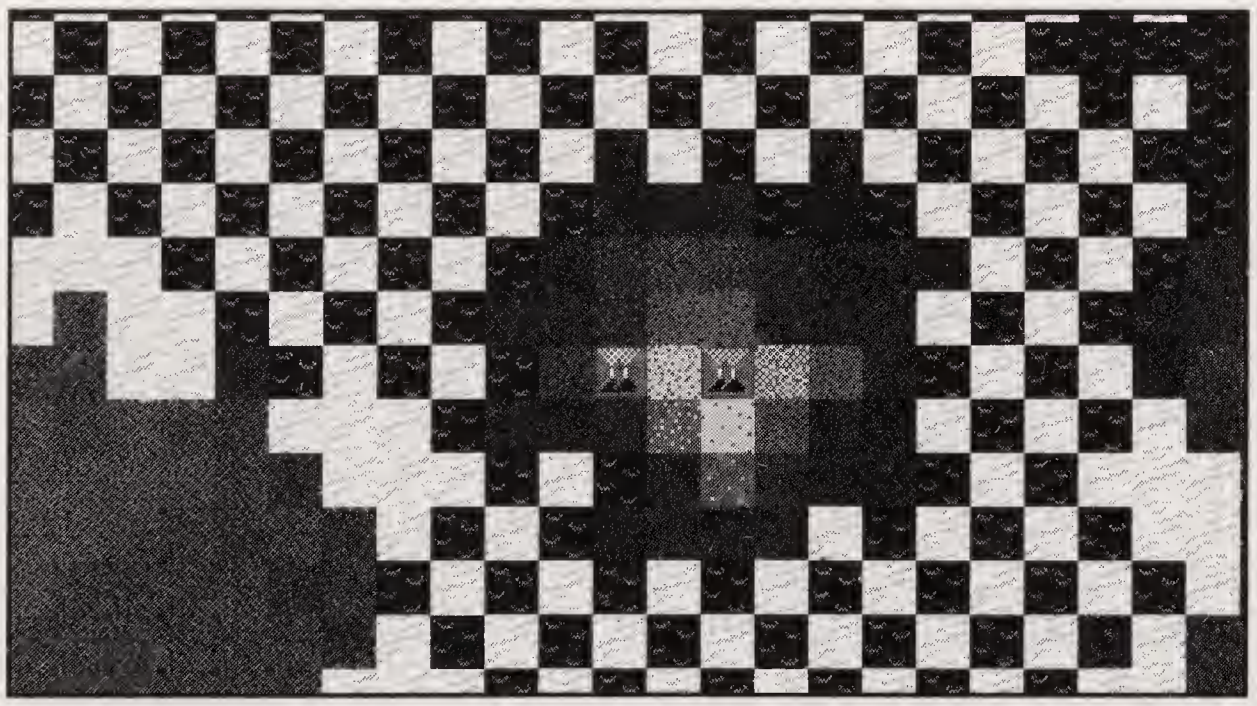
Events can move very rapidly now. You should still have plenty of energy units, so you could move back to Tharsis Monte and drop two Vaporators to create moisture for the benefit of the plants you'll soon begin to grow. An alternate, and safer plan is to build an island in your ocean and place the Vaporators there. Otherwise, you may find out the hard way that if the Vaporators get burned in a fire, your biomes will rapidly disappear. On the island, no biomes will form and your gadgets will be safe.

15. Find a spot in the middle of the ocean and use the Set Altitude tool (arrow up) to build a small island.

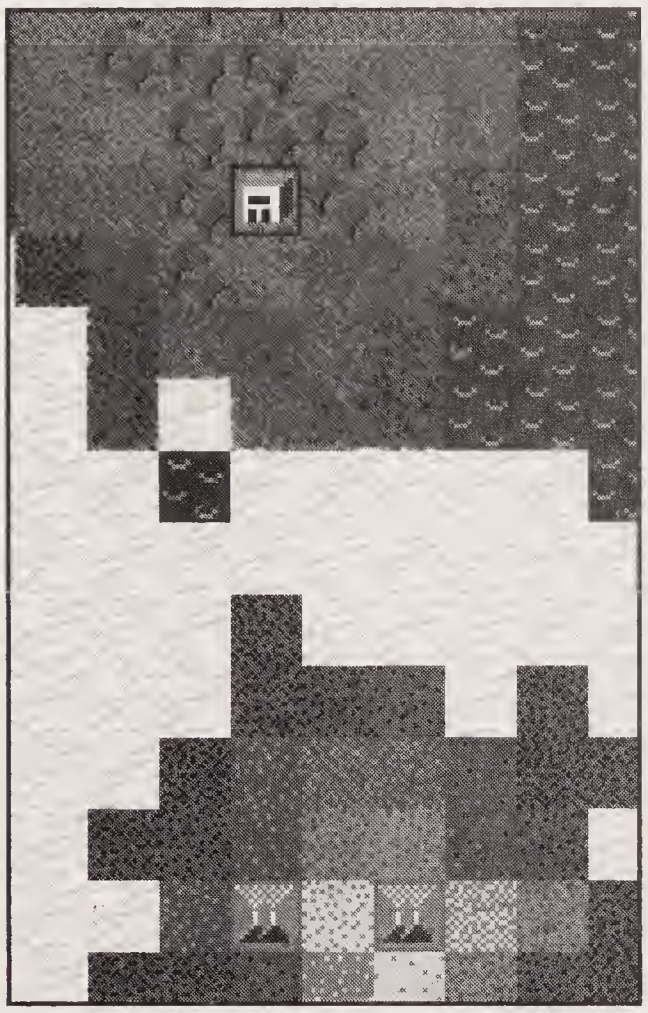
16. (MAC) Place two Vaporators on the island.

16. (IBM) Place one Vaporator on the island.





It may not seem possible, but conditions are already good enough for the high tech plants of the nanotech age, so you want to pick a spot to begin growth, then place a Biome Factory there.



The biome factory at the top is ready to move.

17. Find a place that isn't too high. A low-altitude area in the equatorial belt is best.

18. Place a Biome Factory in the area you've picked.

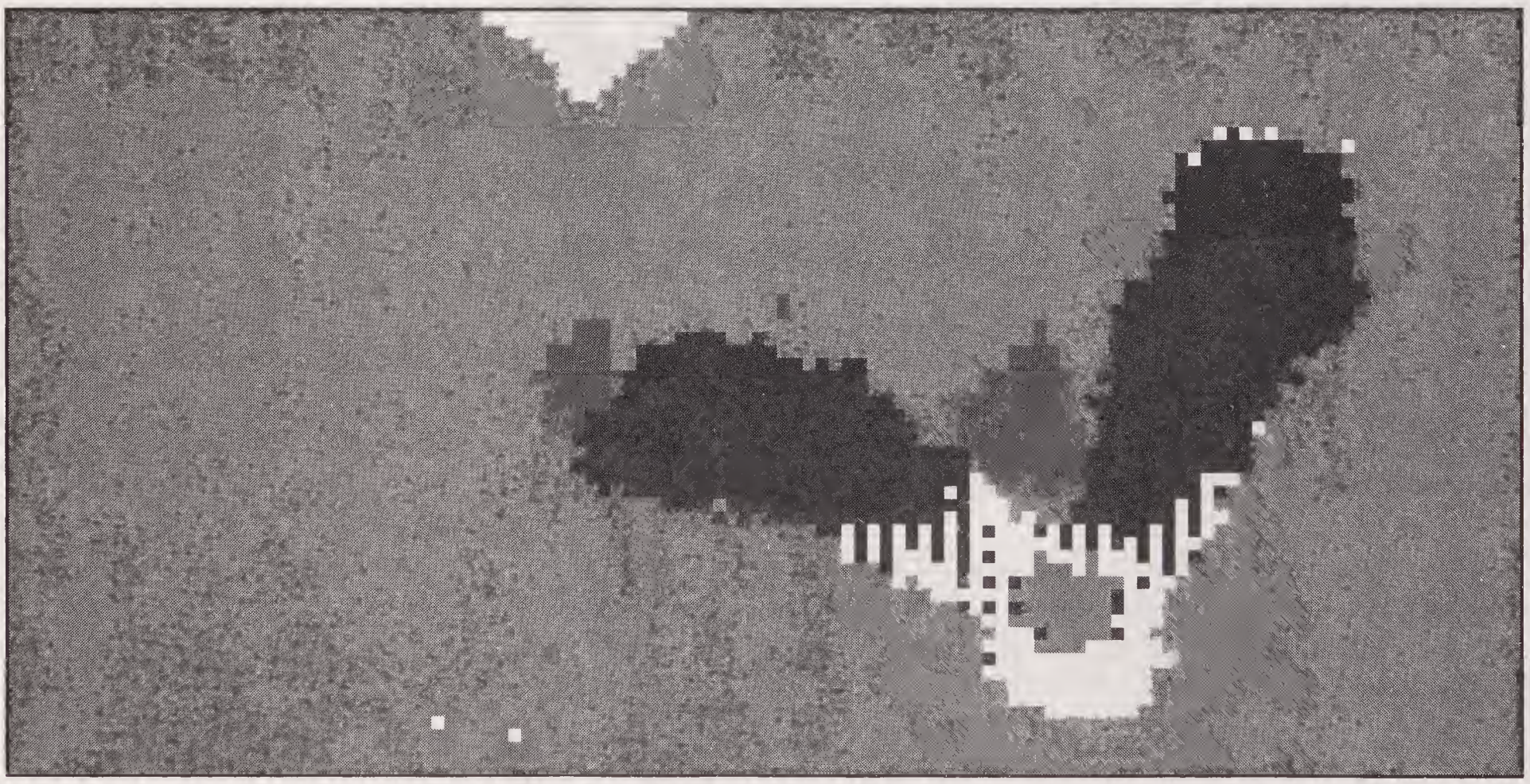
The trick to using the Biome Factory is to move it from place to place. Once a biome has begun to spread, use the Mover tool and change the location of the Biome Factory. One good guideline is to move it to a different altitude. We've most consistently found that we get forests and boreal forests on Mars. The boreal forests tend to grow in the higher altitudes and the regular forests in the lower and hotter areas. Moisture also affects the choice of biome for an area.

Another trick is to watch the Map window. New biomes will appear there before they show up in the Edit window.

19. When the Biome Factory has created a healthy patch of green, move it to a new location.

Now that you have begun the process of creating biomass on the planet, you'll find some changes will take place in the

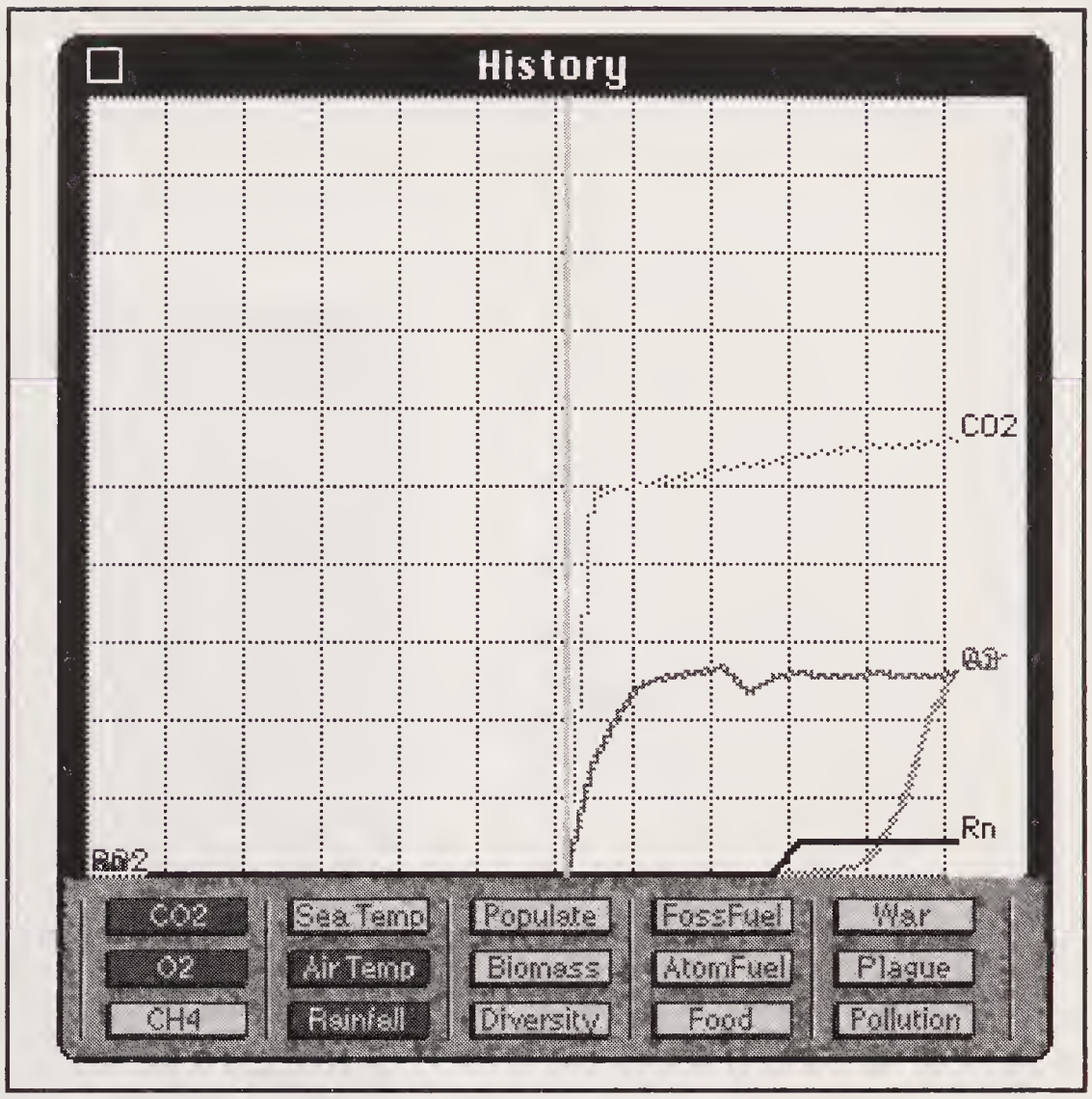
The Mars map circa 25 years. Note the two patches of green biomes spreading out.



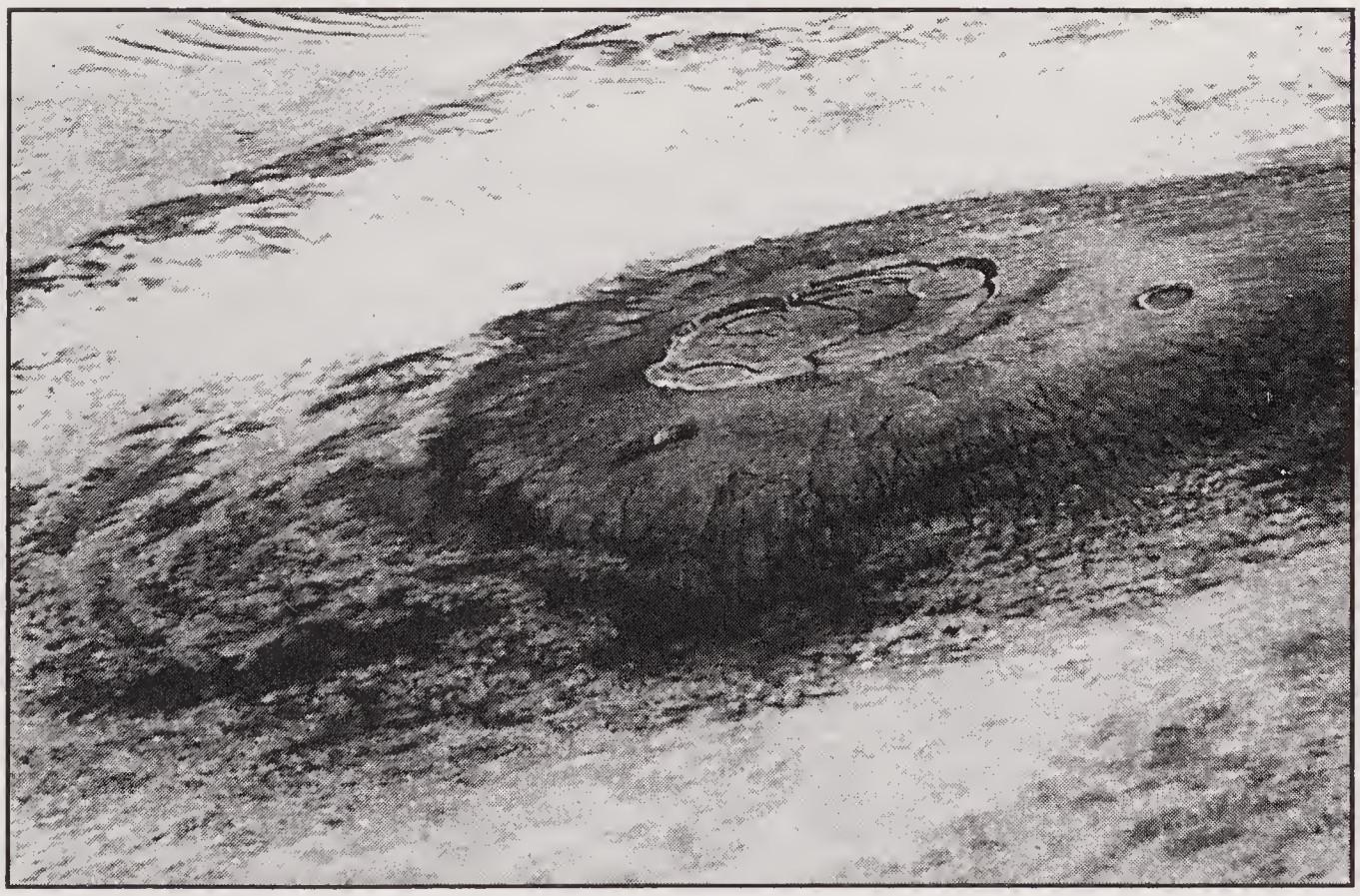
atmosphere. The progress of the planet may not seem too smooth, and the temperature and rainfall may rise and fall sharply. Oxygen and carbon dioxide levels may oscillate as well. But as long as the biomes continue to spread, you're reaching your goal. Again, if you take more time to build up the atmospheric pressure at the beginning, even before creating oceans, and certainly before creating biomes, you'll have a more stable planet.

As you continue to move the Biome Factory from place to place, try to let your energy units continue to build. You'll need at least 1500 EU to drop an Iron Age city on the planet. Depending on which version of SimEarth you're playing, you may already have enough energy units to drop an Iron Age city. We recommend that you wait at least that long, though you can also wait longer and drop an Industrial Age city. However, Iron Age will work just fine.

As soon as your energy units reach 1500 and there is a healthy area of thriving biomes, you can place an Iron Age city in the nicest neighborhood (somewhere near the equator

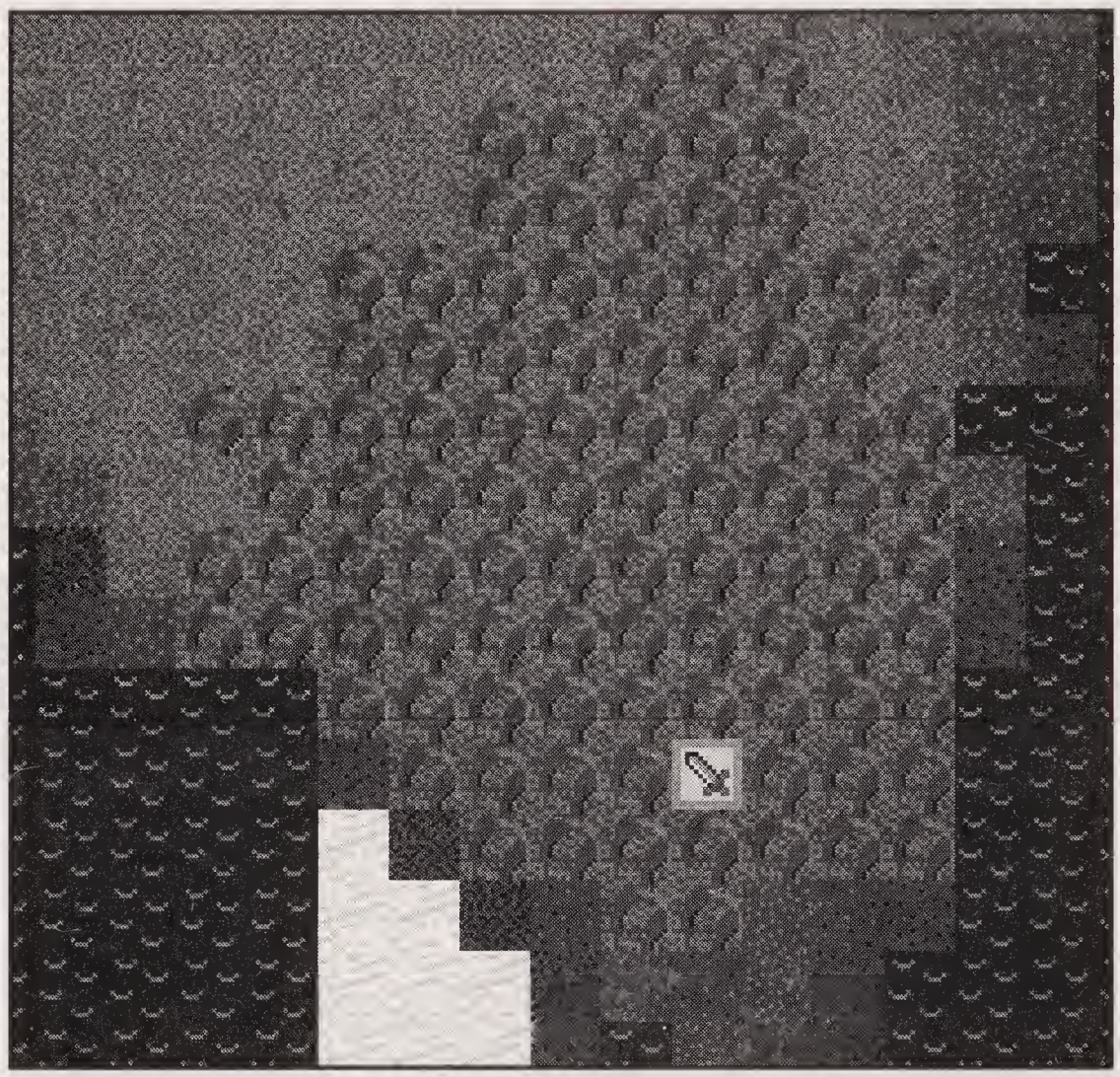


Mars: The History window at 25 years.



Olympus Mons is the largest volcano in the Solar System. At about 17 miles high, it is three times as tall as Mt. Everest. Scientists think it formed over a hot spot in Mars' surface, and, without tectonic plate activity, it just got higher and higher. That's what Hawaii would have been if the Earth's crust didn't move! There would be good skiing, if you wore a pressure suit!

and perhaps near the water). Of course, the biomes haven't yet covered the planet, and consequently much of the surface is uninhabitable. Moreover, the oxygen content of the atmosphere is far from Earth-like yet. Still, your people will survive, admittedly under adverse conditions.



20. Place an Iron Age city in a stable biome area. Find the warmest place you can.

Don't trust the information you get using the Examine Tool on the Edit window, though. The temperatures you'll see won't be accurate. Surprisingly, though, your civilization can succeed even where temperatures are very low. As long as they have good, growing biomes to live in, they seem to be OK.

21. As soon as you can, raise the Agriculture setting on the Civilization Model Control Panel to its maximum.

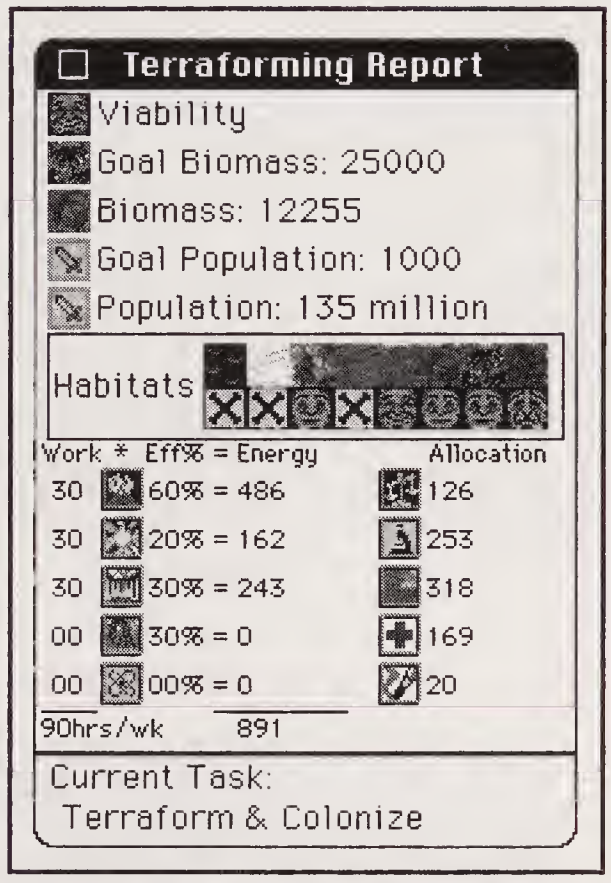
22. Next, raise the levels of Hydro/Geo and Solar/Wind energy to maximum.

23. Finally, raise Science a few notches, lower Philosophy, Medicine, and Art/Media.

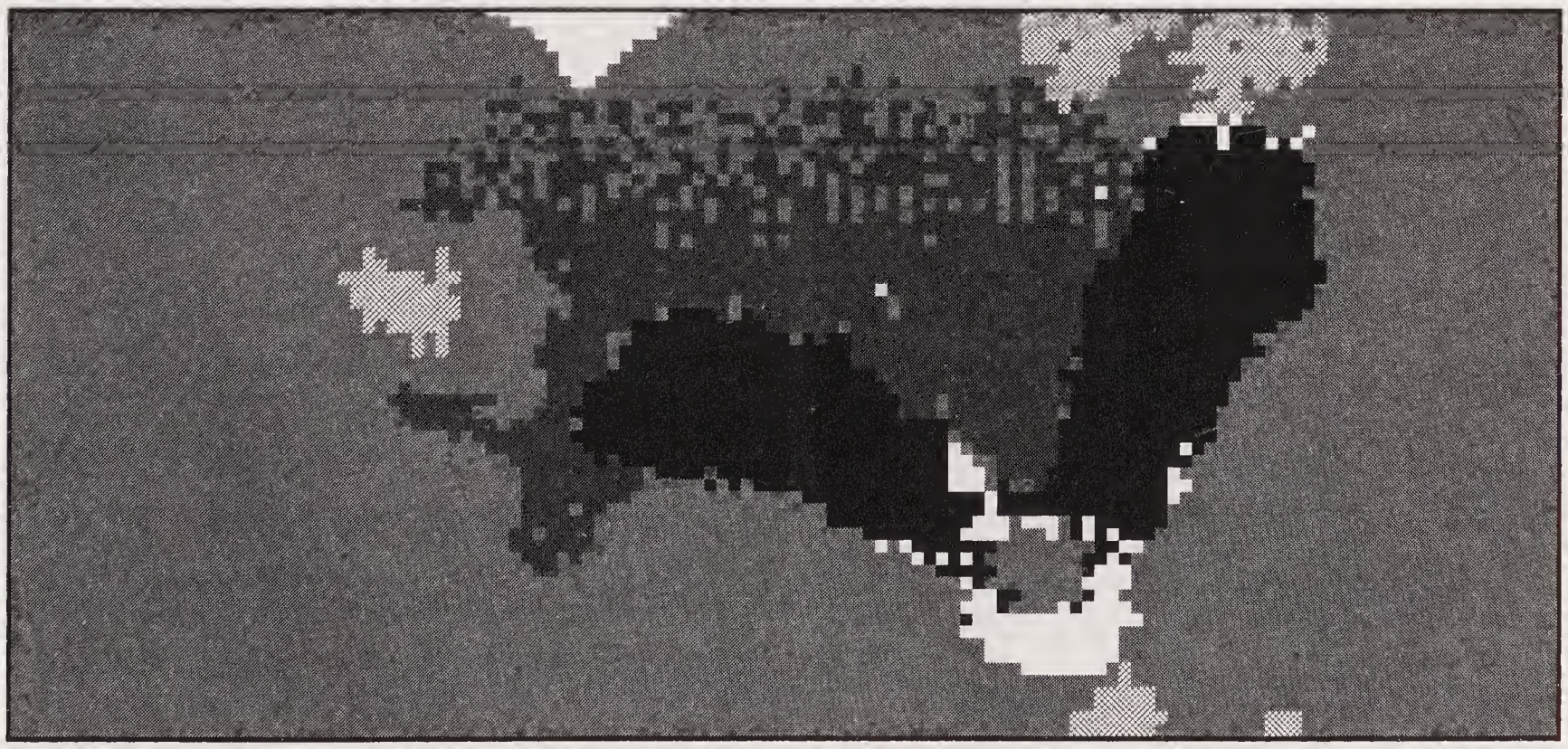
Now you've set the formula for your civilization to spread quickly. If you discover that too many plagues occur, raise Medicine.

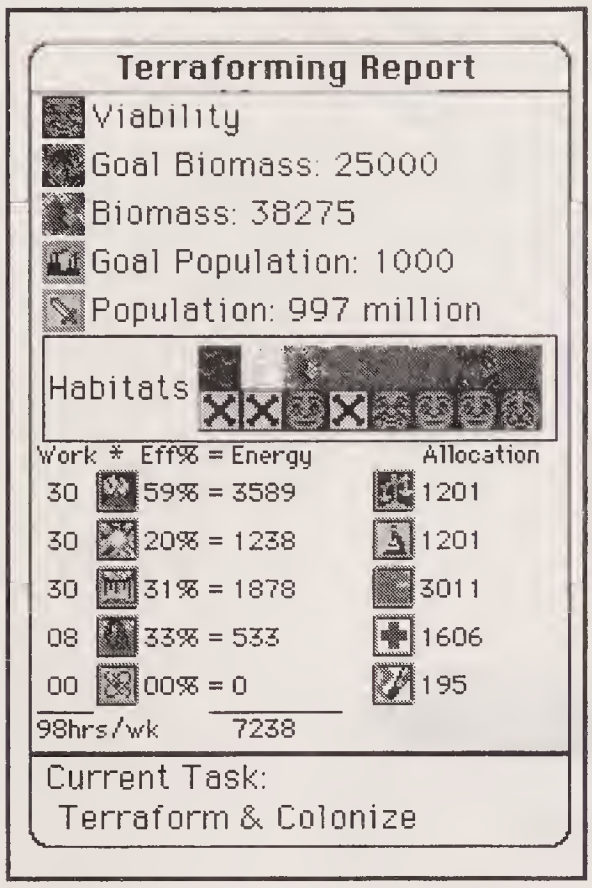
24. Keep moving the Biome Factory to be sure that your people have places to move to.

You'll probably want to switch between the Biomes map and the Civ map in the Map window. That way you can track the progress of your people and your plants alternately. Also, remember to keep an eye on the History graph, the Atmospheric Composition Graph, and the Terraforming Report. You may find that the atmosphere is unstable and especially oxygen levels rise and fall. A sudden loss of biomes can be explained by a dip in oxygen levels—sometimes because of massive fires. Usually, though, the situation corrects itself.



Here are the Biomes Map and the Report window at about 75 years.





Here's the Report window just before Mars becomes terraformed.

You may want to place another CO_2 Generator on the island. And be careful that your other generators don't get burned in a fire. Sudden changes in atmospheric gas levels may be an indication that one of your gas generators got fried. That's why you build the island. To be safe, you might move the original generators to the island. Without Gaia regulation, no biomes will appear there, and therefore no fires can break out.

You might also try using fossil fuels. There shouldn't be any on Mars, but maybe you can synthesize some. Anyway, that's another way to increase the carbon dioxide levels, and therefore the temperature of the planet.

Unless something catastrophic happens, your biomes and your people should grow together, covering the planet. If you're lucky, the planet will be terraformed before 100 years have passed.

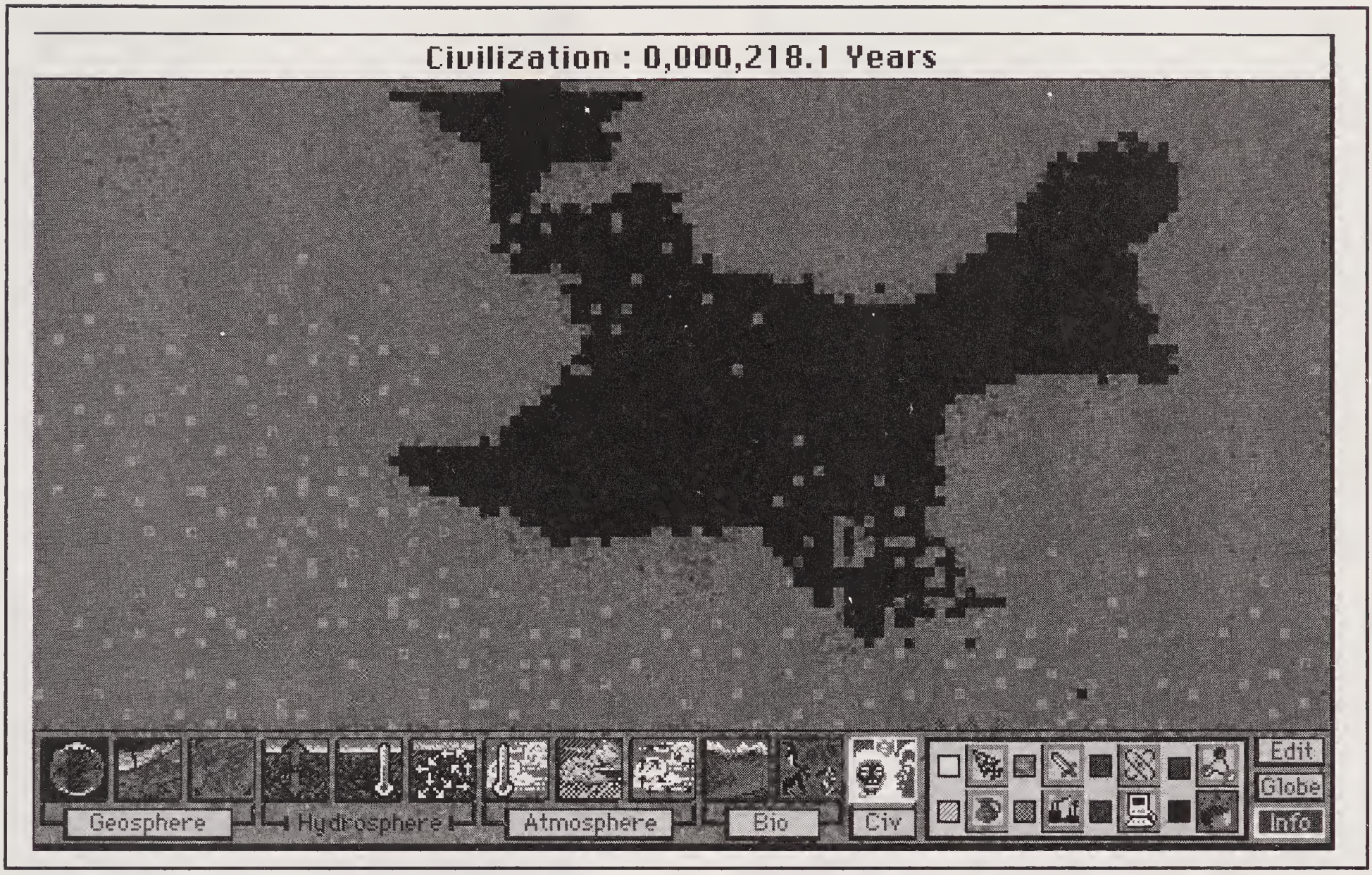
A Trick in Easy Mode

This only works in Easy mode, but if you want to have a lot of energy to work with, drop a Nanotech city on the surface of Mars right at the beginning of the terraforming simulation. Any other civilization would die in the poisonous, thin atmosphere and frozen wastes, but not the Nanotech folks. They can live just about anywhere. The advantage is that now, each cycle of the SimEarth clock gives you back eight energy units. Your energy will replenish so fast that you can proceed with the rest of the terraforming task with virtually no energy limits.

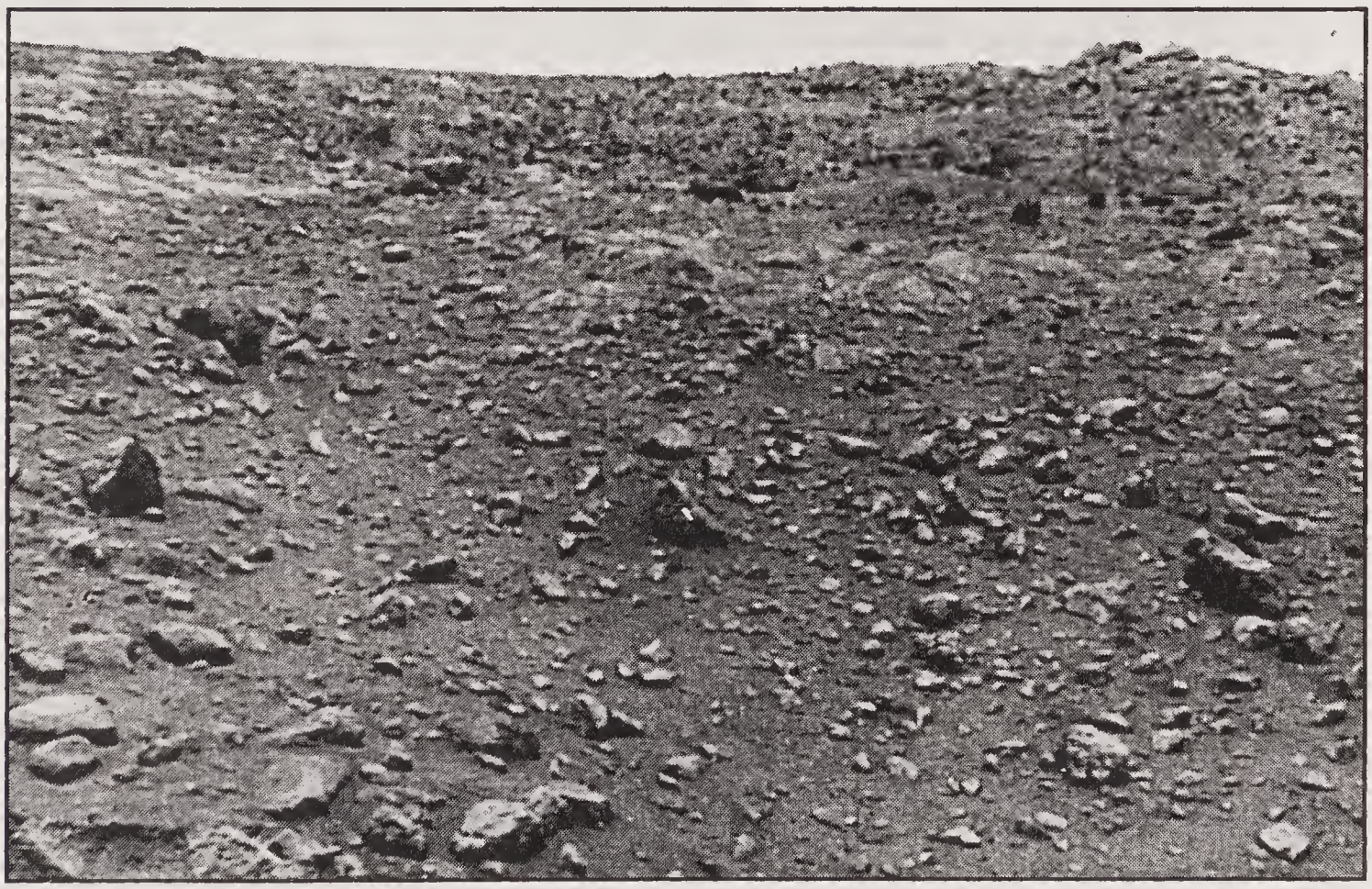
Mars—The Hard Mode

Before trying Mars in the Hard mode, try it in the Easy or in the Experimental mode to find out basically what works. Run through the previous section to understand the basics of Mars.

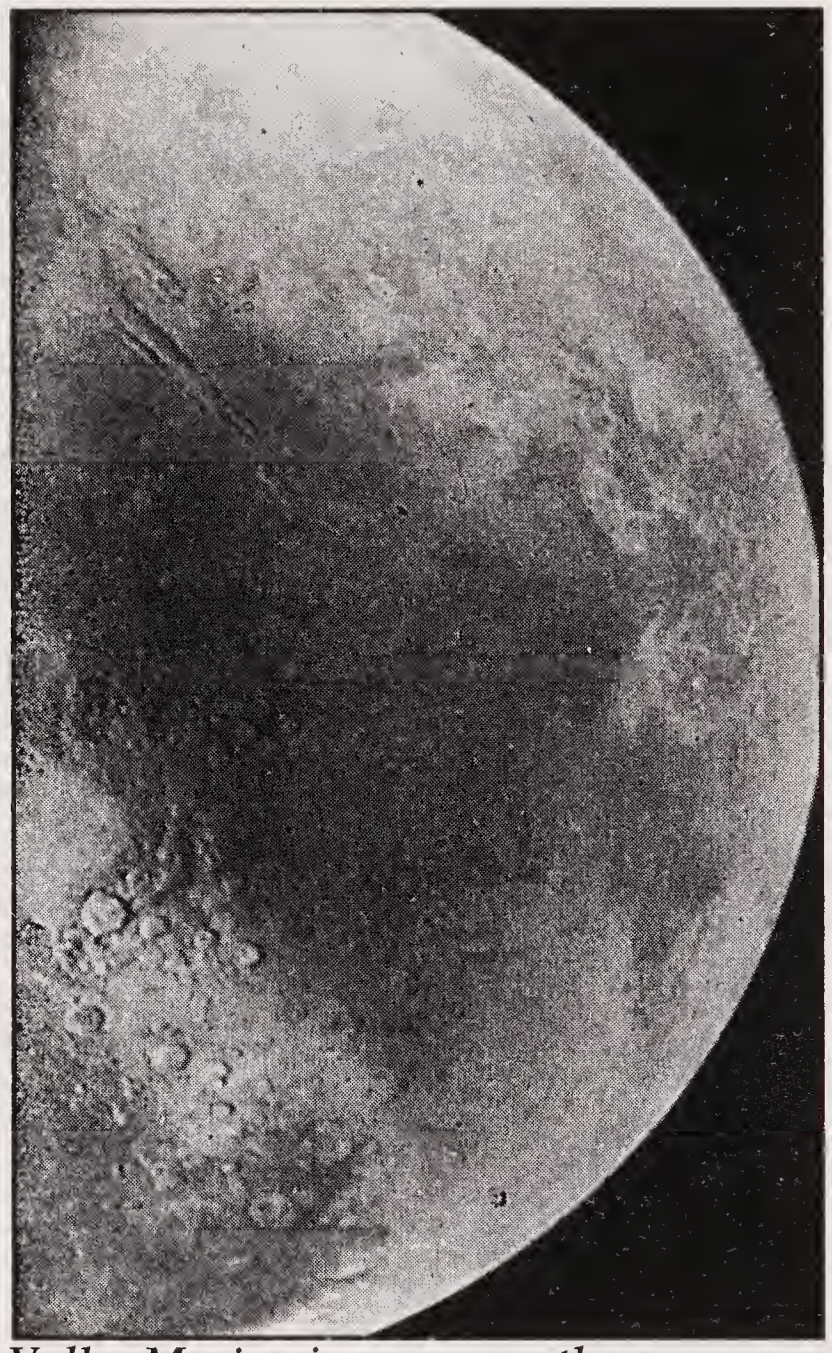
In the terraforming models, Gaia regulation is turned off. Therefore, the only difference between the Average and Hard modes of play has to do with the amount of randomization that occurs in the model controls. Each time you start a new Average or Hard game, the model controls will be set differently. This can work to your advantage, or to your disadvantage. For instance, when terraforming Mars, you may get a great deal of fluctuation in settings for CO_2



Here's Mars being terraformed in the Hard mode.



Typical lifeless Martian terrain.



Are these the canals of Mars? The left image shows the Valles Marineris, a canyon the averages two miles deep and spans about 3,000 miles.

MARS

The canals of Mars. Millions of dreamers have grown up with this evocative picture in their minds. The idea that orderly systems of canals existed on Mars seemed compelling evidence that intelligent life had lived (and might still live) on the Red Planet.

The canals were originally the discovery of Giovanni Schiaparelli, an Italian astronomer who, in 1877, spotted what appeared to be regular, straight lines on the surface of Mars. Calling them canali (Italian for channels), his discovery was Anglicized into canals.

The American astronomer, Percival Lowell, studied these markings for years, becoming convinced of their authenticity. He mapped them and studied them, but was unable to get a closer look at the Martian surface to find out what he was seeing.

Almost 100 years after Schiaparelli's first announcement of the canali, the myth was shattered. Viking 1 sent back the first photographic images of the Martian surface. Combined with orbital images from other robotic cameras, they proved that Mars was as

bleak and lifeless as people's hopeful and dreaded images of green Martians or people riding six-legged creatures on its surface as in Edgar Rice Burroughs' John Carter fantasies. Once, long ago, Mars might have supported life, but there seems little danger now of the mysterious visitors from Mars. From somewhere else, perhaps, but not from Mars.

Jonathan Weiner in *Planet Earth* talks about floods that happened on Mars long ago. He compares them to a massive event that happened here on Earth about 13,000 years ago. Glaciers had formed a natural dam that blocked water behind the mountains near the Idaho and Montana borders. The resulting lake was 3,000 miles across and 2,000 feet deep. Apparently the dam broke and water crashed across what later became known as the Scablands in southern Washington state. The wall of water was possibly as much as 30 stories high and tore the land surface down 100 to 150 feet. In fact, this flood contained more than ten times the volume of water as all the world's rivers flowing today.

As big as the Scablands flood was, the great floods on Mars would have made it seem like a trickle. The Scablands would be lost in the vast floodplains on Mars. Somewhere back in time, Mars had huge deluges which gouged out the land and left huge dry riverbeds. The evidence strongly suggest billions of tons of water flowing rapidly across the surface.

Some scientists believe that vast quantities of water may be trapped beneath the surface of Mars, frozen in a layer of permafrost miles thick. Others believe the planet to be dry. Certainly any liquid water would freeze or evaporate away in the thin atmosphere of Mars as it exists today.

James Lovelock describes his vision of Mars in *The Ages of Gaia*.

> If you look at the lunar-like surface of Mars you will see that the channels and flow systems, which so strongly suggest the presence of water, are ancient indeed; almost all date to the period before 3.5 eons ago when planetesimal impacts were frequent. Mars may have had a thicker atmosphere greenhouse and a warmer climate; also, there may have been heating from the impacts. Four eons ago, the Sun was at least 25 percent less luminous than now. If Mars is frozen now, a thick blanket would have been needed then to sustain an atmosphere and flowing water. Since those distant times, the Sun has warmed and there have been more large planetesimal impacts, although less frequent than in the early days. In spite of this no signs of further water flows are seen. The present conventional wisdom that envisages an ocean of frozen water 100 meters thick may be wrong. Not enough account has been taken of the probability that Mars, like the Earth, was originally rich in chemical substances that react with water to form hydrogen that escapes to space. The water may once have been there, but the escape of hydrogen left oxygen behind, not as free oxygen, but chemically bound in nitrates, sulfates, and iron oxides.

He continues elsewhere:

> If you were to visit Mars on a sunny summer afternoon in latitudes corresponding to those of Buenos Aires or Melbourne you might be surprised by the warmth of the climate. Daytime temperatures could be as high as 70º F. If only the air were breathable, it would be a shirt-sleeve environment. But on other days it might be below freezing. And always when the Sun went down the temperature would fall, with frightening rapidity, to reach -120º F by midnight; cold enough for solid carbon dioxide to form a frost of dry ice at the bottom of the valleys or depressions.
>
> The ground beneath your feet would seem like desert on the Earth. But this would be an illusion, for few deserts anywhere on Earth are devoid of life. There is almost everywhere on Earthly deserts a thin cover of bacterial growth called the desert pavement. There is no soil on Mars, only a lifeless mix of rocks of all sizes from dust to boulders that has been given almost onomatopoeically, that dry harsh name, regolith. Mars is not yet ready for life; it is not only inhospitable to any form of life, it is also poisonous and destructive to organic matter. The air at the surface of Mars is in a chemical state like that of the stratosphere above the Earth. If the stratospheric air 10 miles above our heads could be compressed without changing its composition, we could not breathe it. Ozone is present there at 5 parts per million. Ozone may shield us from solar ultraviolet radiation, but at this abundance it is painful and soon lethal to breathe. The surface of Mars after a planetary lifetime exposed to such an atmosphere is rich in exotic chemicals, such as pernitric acid, that can rapidly destroy seeds, bacteria, or indeed almost all organic matter. Mars is no place for gardening.

Absorption or Reproduction Rate which will affect how the biosphere operates. Or you might get a very high albedo for the surface, which will tend to keep the planet cool (not what you want). Since you can't control any of the model control panels except the one for civilization, you just have to deal with what you get.

One thing is constant, however. Every time you play, the setting for Greenhouse Effect is off, and the Solar Input is very low. Also Erosion is very low and Volcanic Activity is off.

The secret to success in the Hard mode is to be patient. Place a few CO_2 Generators, then wait for the atmospheric pressure to rise and your energy units to recharge. When you can afford to, drop ice meteors to form oceans and use the Set Altitude tool to expand them. In fact, you'll follow basically the same steps you would follow in the

Easy mode, but each step will take longer. You can probably get away with using only one Vaporator, though. Don't forget to put it on an island, safe from fires. With patience, luck, and skill, you should be able to terraform Mars within 200 years if all goes well, and certainly within 500 years even under adverse conditions.

Perspective from Venus. Taken from the southeast rim of Lakshmi Planum. Danu Montes rises 1.5 km. in the background.

VENUS

Once we imagined that Venus might be a paradise beneath its cloud cover. People fantasized about steamy jungles of exotic extraterrestrial life forms teeming on the Venusian surface. Our sister planet, named after the beautiful goddess of Love.

But a more apt analogy would be Dante's Inferno. Venus is hellish, hot, poisonous, and volcanic. The atmospheric pressure is about the same as the pressure at 3000 feet below the surface of the ocean on Earth. The greenhouse effect has gone wild with temperatures reaching 900º F. The atmosphere is largely carbon dioxide, which probably accounts for the intense greenhouse conditions.

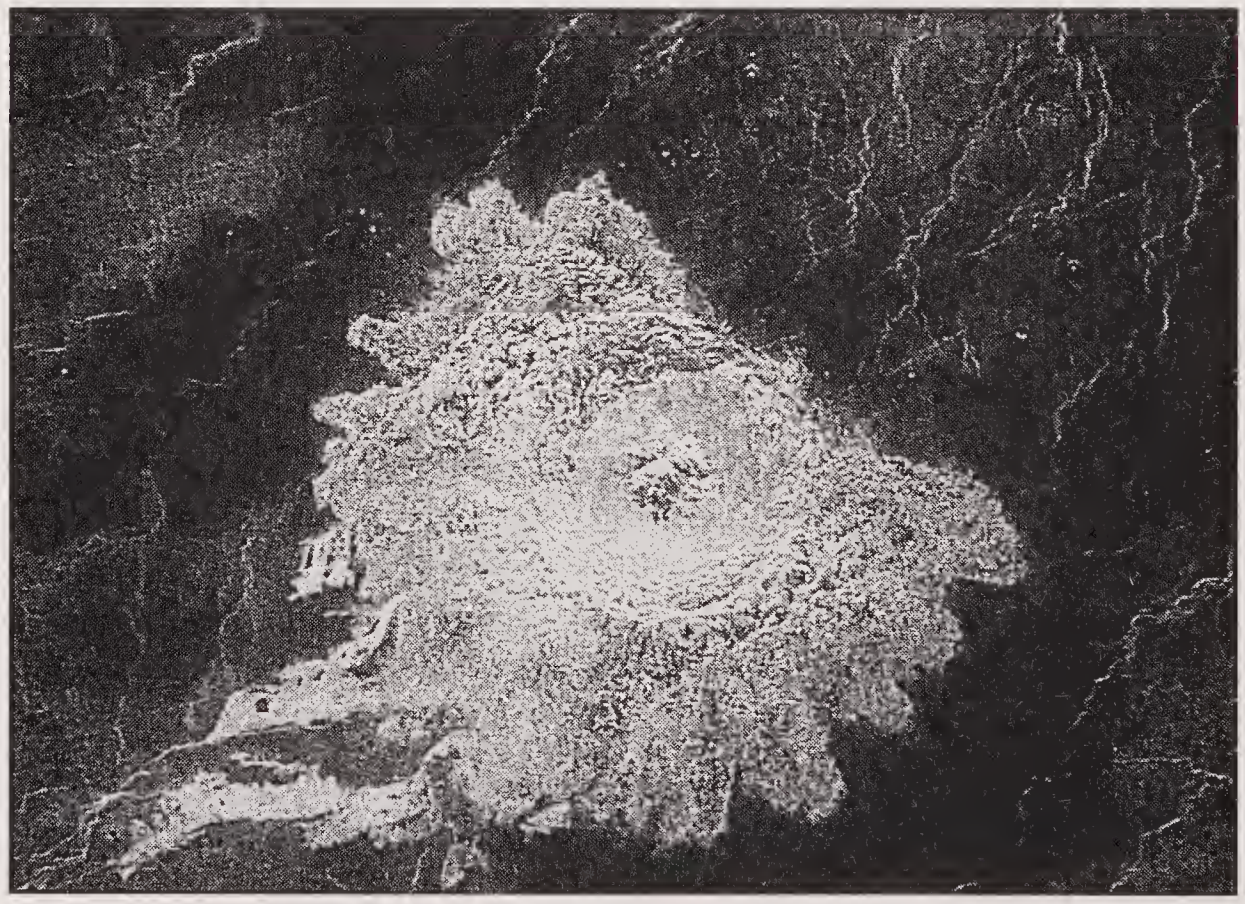
Rains fall regularly, but not the gentle life-giving water we know. To say that Venus has acid rain is an understatement. Sulfuric acid is the main liquid in Venusian

clouds and rain. Even though they are made of titanium with windows of diamond and sapphire, probes sent into this corrosive atmosphere generally die a quick death from the corrosion, the gargantuan 200 mile per hour winds and the immense pressures before sending a single message back. Those that do survive the descent have lasted little more than an hour.

So you've got your work cut out. To terraform this hell into a garden is going to take all your skills and quite a few of your nanotech gadgets.

The basic strategy you'll employ is to use Oxygenators to replace the carbon dioxide with oxygen. This will reduce the greenhouse effect and eventually reduce the planet's temperature. Once the temperature has fallen enough for liquid water to exist without boiling instantly away, it's time for an ice meteor or two. With oceans, you'll start to get a more beneficial environment. Place some Eukaryotes in the water to help generate oxygen, then place a Vaporator or two. Finally, place a Biome Factory and watch the fun. Then, place a city in the planet once it's ready.

Before you begin to terraform the planet. it's good to understand your goals. The first goal is to create a biomass of 25,000. The second goal is to get a human population of one



The Aurelia impact crater.

billion (1,000 million). These goals are stated in the Terraform Report window.

Let's look at several different ways to terraform Venus. First, in the Easy mode:

Venus—The Easy Mode

In the Easy mode, you have a maximum of 5000 EU. That should be plenty, but you'll still have to make some decisions. For instance, do you spend most of your energy on Oxygenators? Or do you save some for other devices you'll need. The trade off is that with more Oxygenators, you should be able to bring down the air temperatures faster, and therefore complete the terraforming job quicker. But if you run out of energy, you'll have problems later on. Let's try it with eight Oxygenators (total cost 4000 EU).

1. **Select New Planet from the File menu and select Venus.**

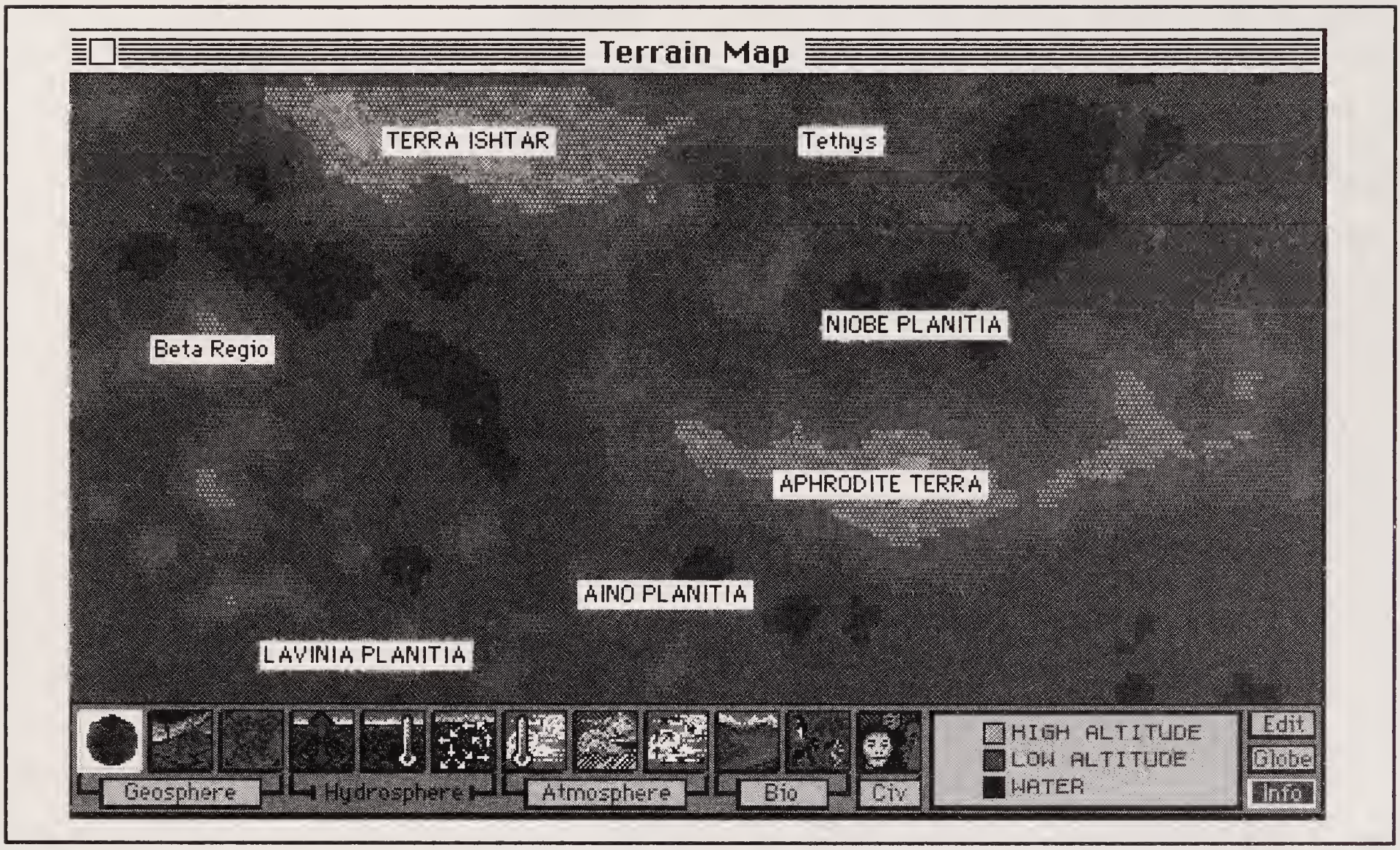
2. **If you have room, open the Edit window, the History window, the Report window, and the Air Sample graph.**

3. **Examine the Report window to see what your goals are: Biomass, 25,000; Population, 1,000 million.**

4. **Select Air Temp., CO_2, O_2, and Rainfall in the History window.**

For the rest of the steps in this section, there will be occasions when the instructions may vary depending on whether you have a Macintosh or an IBM compatible. The steps will be labelled accordingly.

In the next step, you'll place several Oxygenators on a high mountain. Place them



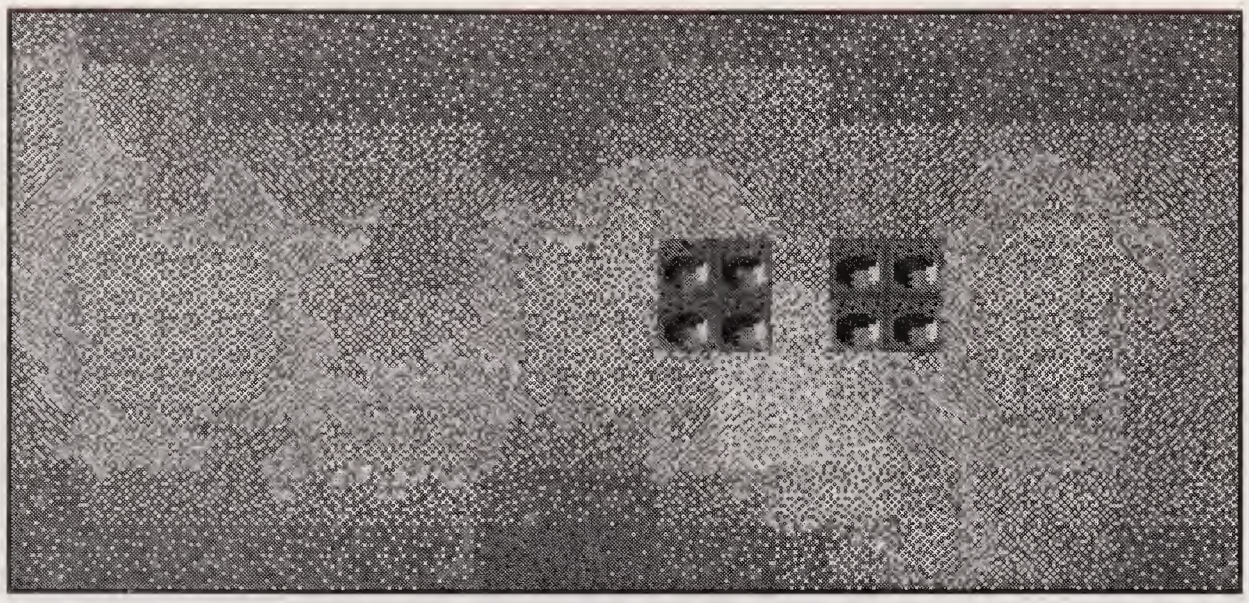
in square groups of four each. Later, when you need to remove them, it will be easier if you group them that way.

5. **(MAC) Place eight Oxygenators at the top of the Terra Ishtar mountain range.**

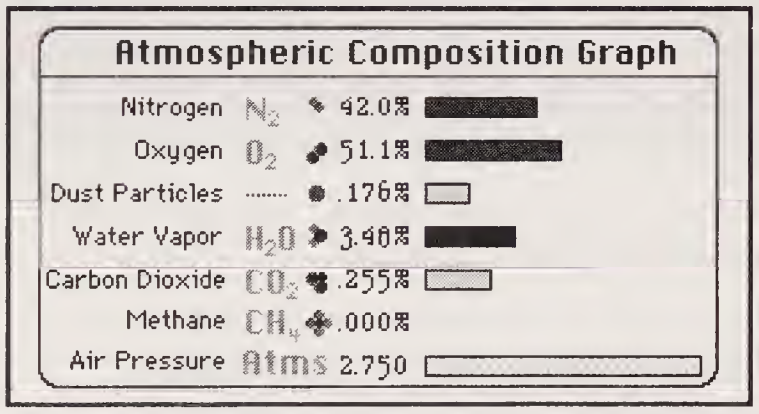
5. **(IBM) Place four Oxygenators at the top of the Terra Ishtar mountain range.**

   To see the names of the main features on Venus, click and hold on the Terrain Map icon in the Map window.

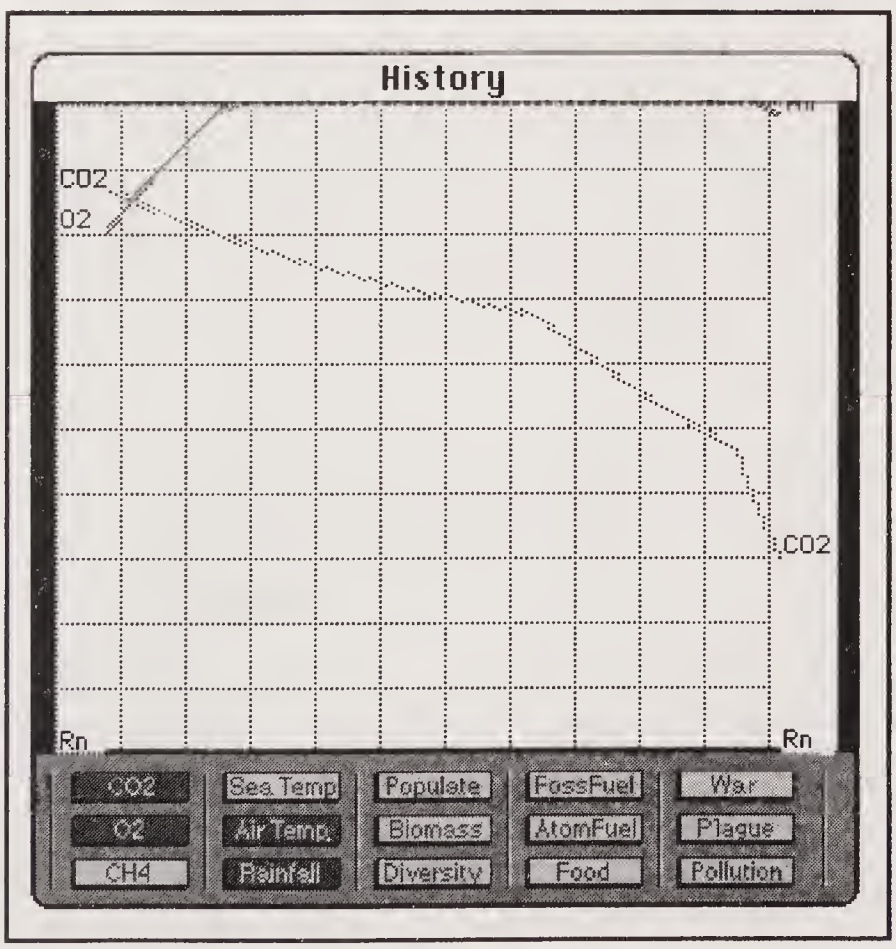
Now wait and watch for a while. Keep checking the History window and the Air Sample graph to see that oxygen levels are rising and carbon dioxide is falling. Also, the water vapor level is falling. Water in the atmosphere also acts as a greenhouse gas.

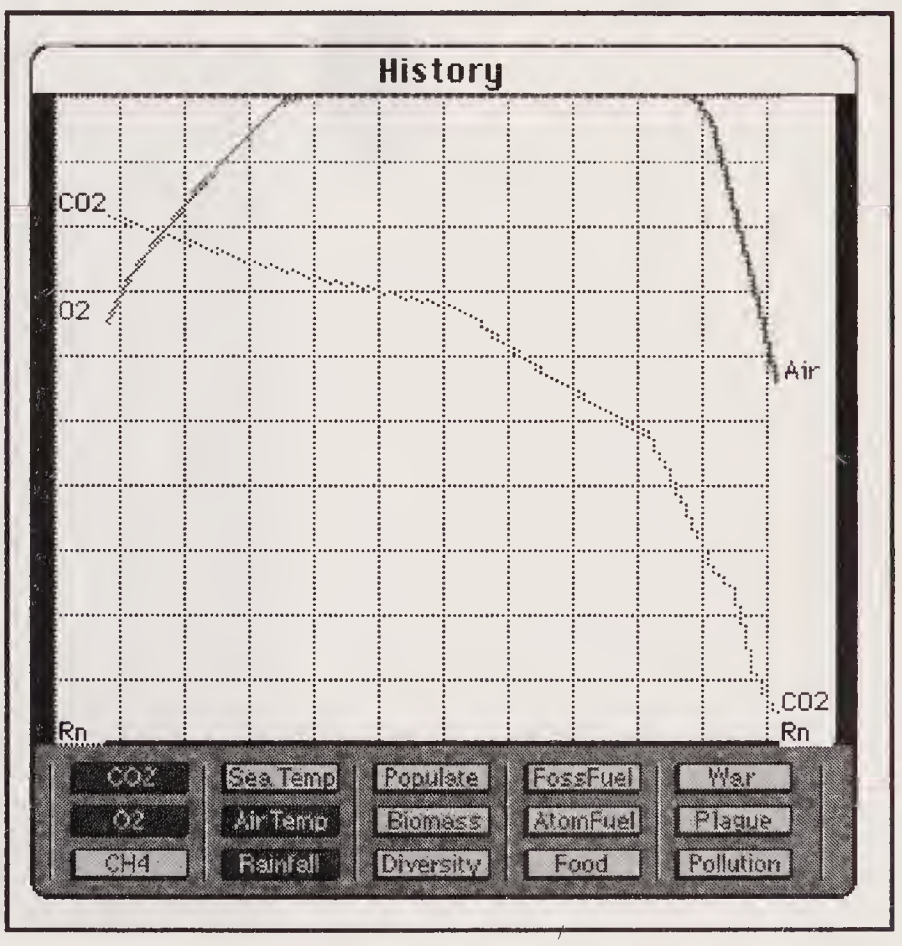


Eventually, air temperature will also fall. It will take many years, depending on how many Oxygenators you placed. You'll find that until carbon dioxide falls below one percent, air temperature remains high. However, by this time the oxygen content of the atmosphere will be incredibly high. In fact, it will eventually reach a point where just about anything would burn up instantly. However, once the air temperature drops, you'll have an opportunity to replace



On the left is an Atmospheric Composition Graph showing the conditions close to the cooling of the planet. Oxygen is very high.
On the bottom are two History graphs. The first shows the air just starting to fall. The second shows the approximate time to drop an ice meteor (see next page).



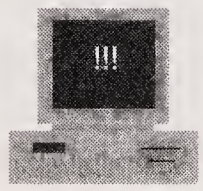


some of the oxygen with nitrogen and get a more Earth-like atmosphere. Fortunately the various nanotech devices you place on the planet seem able to survive the high oxygen levels.

Once the air temperature drops, it really drops fast. Now its time to create some oceans, but first, as soon as you see the Air Temperature level drop in the History window, save the game.

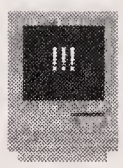
6. From the File Menu, choose Save As and save this game as Venus1.

7. (MAC) Select the Ice Meteor from the Place Life palette and drop one in one of the "seas" on the surface of the planet.



7. (IBM) Select the Ice Meteor from the Place Life palette and drop two in one of the "seas" on the surface of the planet.

We use the sea just east of Beta Regio.



Here's a great SimEarth secret you can use on the Macintosh only. (Sorry PC users!) There's a good possibility that your one ice meteor wasn't enough to cause the oceans to form. However, if you select Ice Meteor again from the Place Life palette, water will appear. You don't have to use the ice meteor, just select it. This works in other scenarios as well. Just select Ice Meteor to raise ocean levels.

8. When water appears, use the Set Altitude tool to carve out some large lakes or oceans on the planet's surface.

Be sure the arrow in the Set Altitude icon points down. The way to use the Set Altitude tool is to begin near the existing water line

and just hold down the button. Now carve a large area, preferably following the lower altitudes. Don't release the button and you'll only pay once for the job. You can carve out a whole ocean for only 50 EU. Be careful,

Who says scientists don't have a sense of humor? The area in the upper picture shows a series of what they call "pancake" volcanic domes. Below is the area they call the "gridded plains" but we think of them as the "griddle" plains.

though. Anything that ends up under the Set Altitude tool is destroyed. That includes your nanotech devices. Also be careful you don't create too big an ocean. You'll want to leave plenty of land for your people to settle.

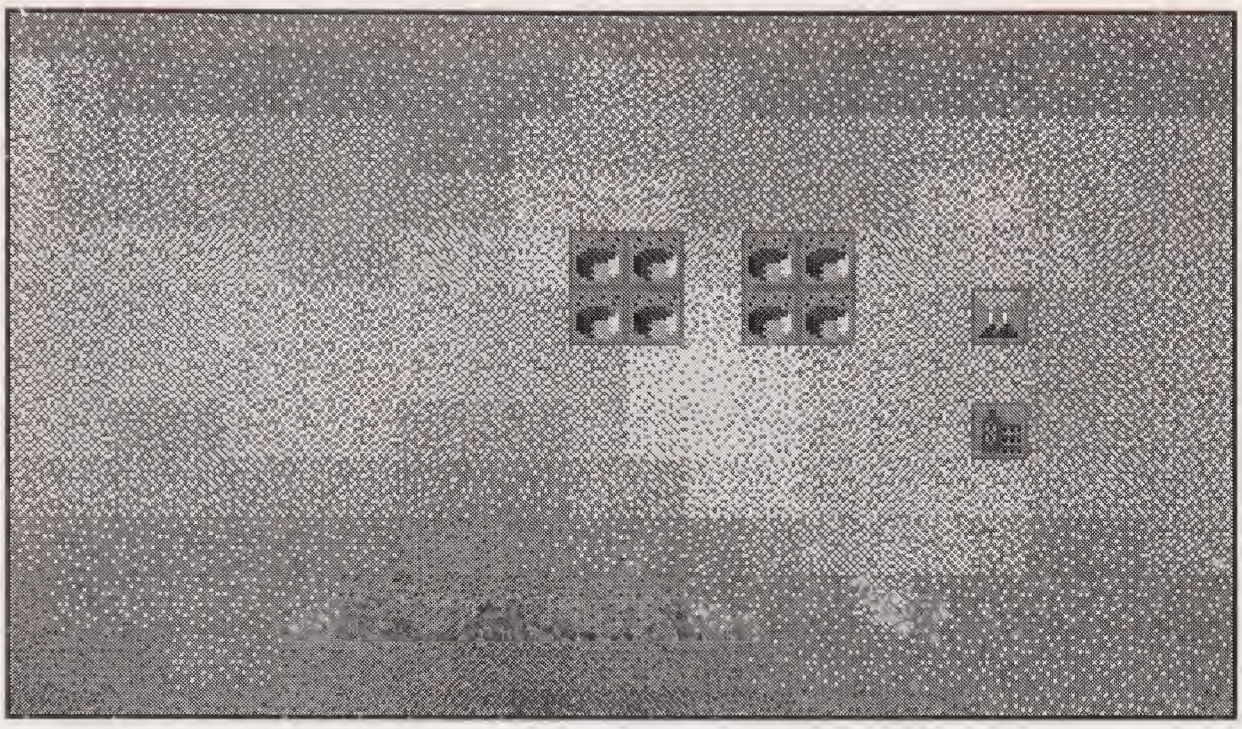
9. Pause the game for a few moments while you read the next section.

Note: If you use the Examine tool to look at the surface of the planet, you may find that the temperatures shown are impossibly high. For some reason, the information from the Examine tool is not accurate. Rainfall values aren't accurate either. You can turn on the temperature and rainfall displays in the Map and Edit windows to get some idea of the situation on the planetary surface, but generally it seems that once the air temperature has fallen and carbon dioxide is gone, the planet becomes suitable for life. Use the History window to monitor the air temperature. It should serve as a fairly useful, if not precise, indicator.

In the next few steps, you'll place some additional nanotech devices and you'll form your oceans. The order in which you perform these steps may vary, depending on how Venus responds to your preparations and on how much energy you have left. Remember, each time you perform these steps, they will respond a little differently. Don't be afraid to save the game at various points and then experiment with different strategies. If one seems to be a dead end, try another. Even if you find a successful approach, you might try to find a better one. Also, since ice meteors cost more energy on some versions of SimEarth than on the others, strategies may need to be adjusted accordingly.

Back to Venus, return to Terra Ishtar and place one or two Vaporators.

10. Place a Vaporator on Terra Ishtar, separate from the Oxygenators.



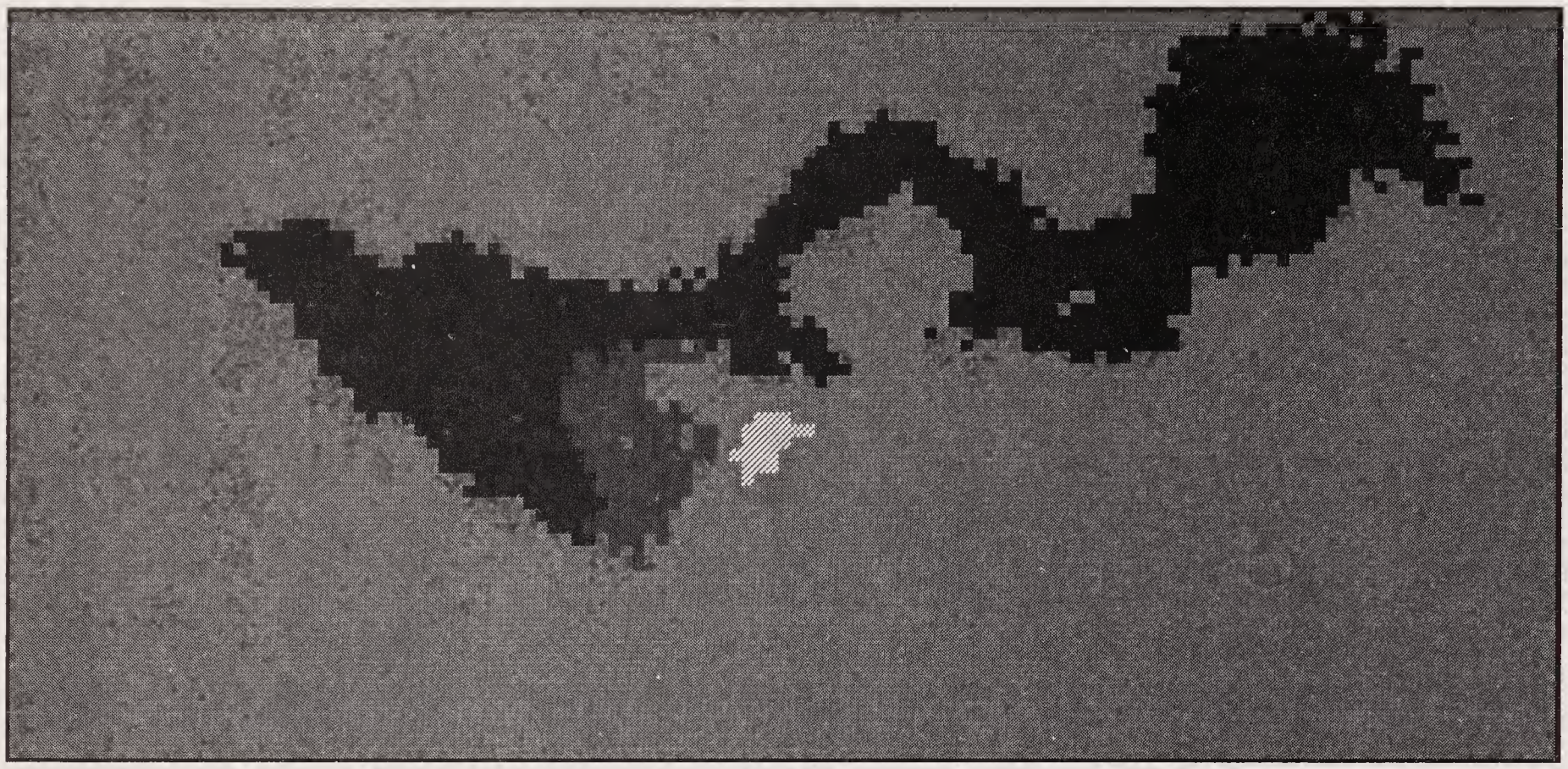
Vaporators affect the moisture in the atmosphere, and therefore the kinds of biomes the Biome Factory will produce. For instance, placing one Vaporator might provide enough moisture for grasslands to grow. But grasslands don't produce all that much biomass. Placing two Vaporators might provide better conditions, and a forest biome may become dominant. Forests produce much more biomass. On the other hand, human civilizations prefer grasslands to forests if given a choice. So there is more than one way to think of Vaporators.

If you have plenty of EU, place two Vaporators, but save at least 1000 EU if you can for the next two steps.

11. **Place an N_2 Generator near the Vaporator(s).**

    The N_2 Generator will help bring the atmosphere toward a more Earth-like composition. If you still have 500 EU, then it's time for a Biome Factory. If not, wait until you've saved up the energy needed.

12. **Find a location that's in the middle altitudes (not too low or too high) and place a Biome Factory there.**



A good start: ocean and biomes.

13. Now start the simulation again at whatever speed you prefer.

14. Place Eukaryotes in the water to keep creating oxygen.

Don't panic if your oceans freeze over (freeze?) or if they even disappear altogether. They'll return. Just ignore such strange occurrences and concentrate on your biomes.

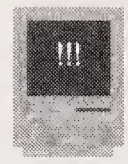
Several factors may affect the kinds of biomes your Biome Factory produces. The major factor that you can control is moisture in the air. If your ocean is large, there is probably more water vapor in the air. If it is relatively small, there may be less. The most desirable biomes to get are forests. That's because they produce more biomass, and one of your goals in this simulation is to produce a certain amount of biomass. Deserts and ice produce none or nearly none. Grasslands produce biomass, but not nearly as much as forests do. Tropical forests are the most dense, but they are hard to obtain in the terraforming simulations. However both boreal and ordinary forests are obtainable.

If your Biome Factory is producing ice or desert biomes, you probably need another Vaporator. In addition,

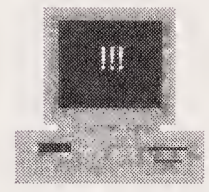
you may want to put the Biome Factory near the water and as near the equator as possible. This is most likely to occur on the Macintosh version.

If your Biome Factory is producing some forests, but lots of grasslands, then you need another Vaporator. This is likely to happen on the IBM compatibles, especially when the ocean is not very large.

15. (MAC) If your Biome Factory is producing either Ice or Desert type biomes, add another Vaporator to the collection on the mount.



15. (IBM) If your Biome Factory is producing grasslands, add another Vaporator. The added moisture will produce forests, high in biomass.



Watch the spread of the biomes, and when there is a pretty healthy block of biomes around the Biome Factory, move it to a new location.

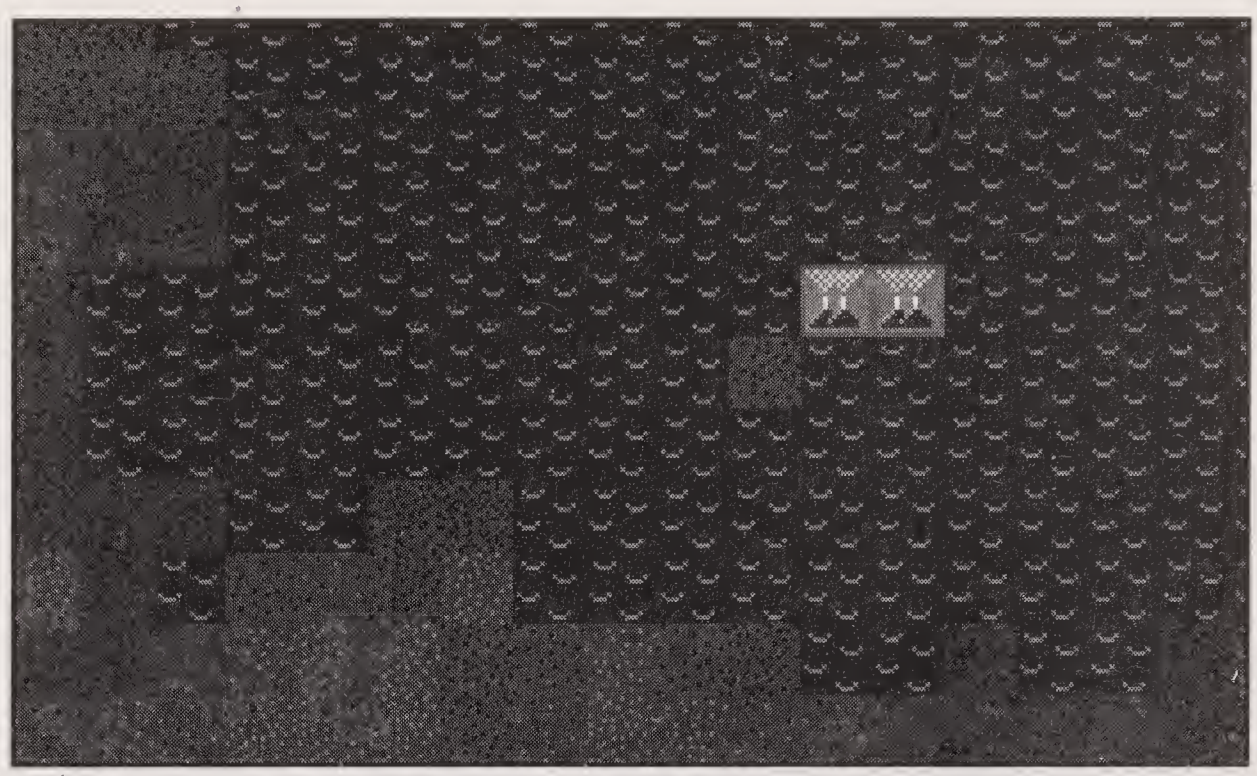
16. Once the new biome is established, move the Biome Factory.

17. Pause for a moment while you read on.

The biomes may spread onto the mountain where your nanotech devices are located. To avoid losing them suddenly to a fire, use the Set Altitude tool to build an island in the middle of the ocean, then use the Mover tool to move them to the island. In particular, move the Vaporators. Don't worry about the gas generators. You shouldn't need them much longer anyway.

18. Use the Set Altitude tool (arrow up) to build a small island in the ocean.

19. Use the Mover tool to move the Vaporators to the island.

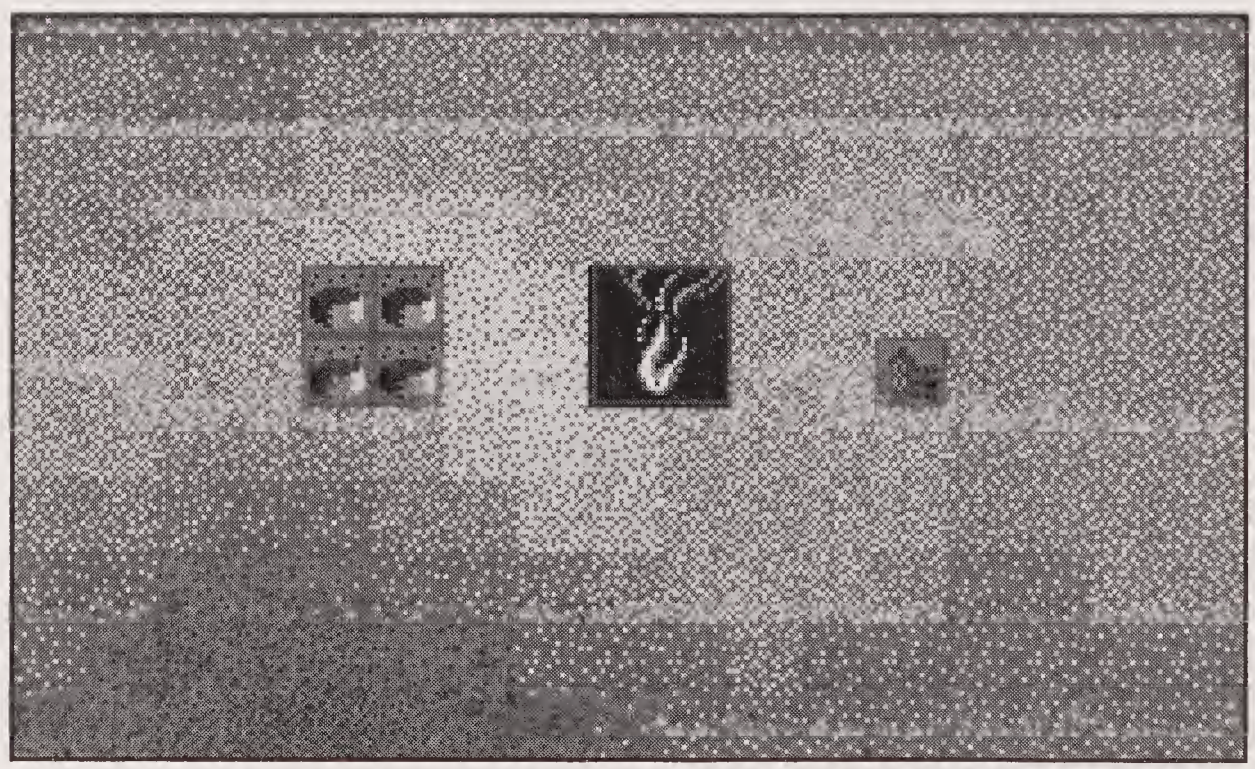


Biomes won't spontaneously move to the island, and therefore, fires won't endanger your vaporators.

Keep moving the Biome Factory to spread plant life quicker. You'll notice that biomes tend to spread out into areas where they can grow, but won't spread to incompatible areas. For instance, forests may grow in the lowlands, but not on the mountains and their slopes. So, move the Biome Factory onto the slopes to start the generation of Boreal Forests in those elevations. Eventually, most of the planet will feature a nice covering of green biomass.

You should see the oxygen levels begin to fall. Fires are breaking out and consuming the oxygen. Meanwhile,

On the other hand, fire works great when you want to trash some terraformers.



your N_2 Generator is replacing lost oxygen with nitrogen, tending toward Earth-like conditions.

Eventually, as your biomes spread out more and more, you may want to place prokaryotes in the water as well. That's because the green plants will be breathing carbon dioxide and exhaling oxygen.

You may also want to destroy some of the Oxygenators once the biomes have covered most of the planet. You can use Fire to destroy the Oxygenators. Remember when you placed them in groups of four? Now, if you were lucky one fire may destroy an entire group. Two perfectly placed fires can destroy all eight Oxygenators. However, it's a matter of luck because the fires themselves only occur on certain blocks of four squares on the map. Therefore, if your placement was good, you'll get four Oxygenators at once. If not, use a few more fires. Or, use the Set Altitude tool to obliterate them. That works mighty well, too.

Before you go ahead and destroy the Oxygenators, save the planet again.

So, to recap the last few paragraphs:

20. **Restart the simulation at whatever speed you prefer.**

21. **Keep moving the Biome Factory.**

    When you've reached the biomass goal of 25,000 and the biomes cover a good portion of the planet:

22. **Use Save As to save the planet under a new name. Call it *Venus3*.**

23. **Place prokaryotes in the oceans.**

24. **Use fire or the Set Altitude tool to destroy half your Oxygenators, but only the Oxygenators.**

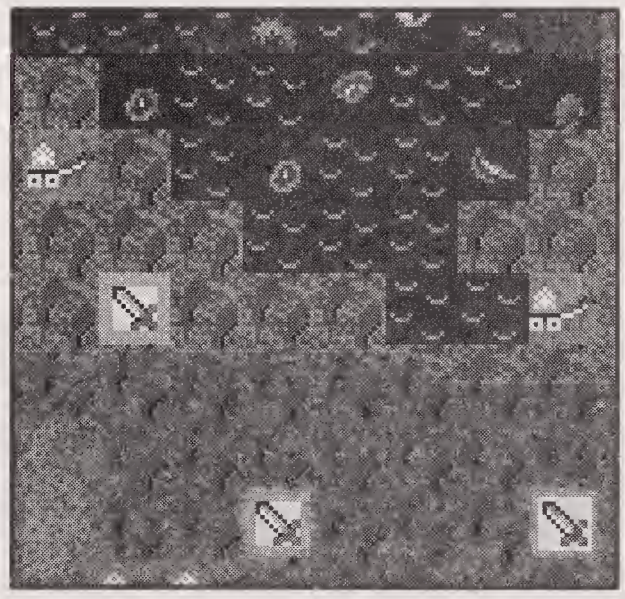
25. **Pause again, and read on.**

Now, as soon as you have enough energy, you can place a city on the planet. Which city you place depends on how much energy you have to spend, or how long you want to wait. The Infotech cities spread the fastest, but they also cost the most. For only 1500 EU, you can place an Iron Age city. If you set the Civilization Model Control Panel settings right, the people will spread and their technology will advance. Probably within about 40 to 60 years, they'll reach the goal population of 1,000 million.

It's probably best to set the Civilization controls first, then place the city. So raise Agriculture to the top setting. If you have lots of energy left over, you can also increase Science a little and increase Hydro/Geo and Solar/Wind to the maximum as well. However, since your energy units will begin to replenish much faster once you've placed a city, you should probably place the city first, then change these settings.

26. Restart the simulation.

27. Set Agriculture to the maximum on the Civilization Model Control Panel.



Which city should you place? It's up to you. Iron Age costs 1500 EU. Industrial costs 2000 EU. Each successive level costs more. The truth is, it may be more efficient to place the Iron Age city earlier than to wait for your energy units to recharge. That's the way we'll do it here, but you can also wait, in Easy Mode, and place Infotech cities for 3000. It's your option.

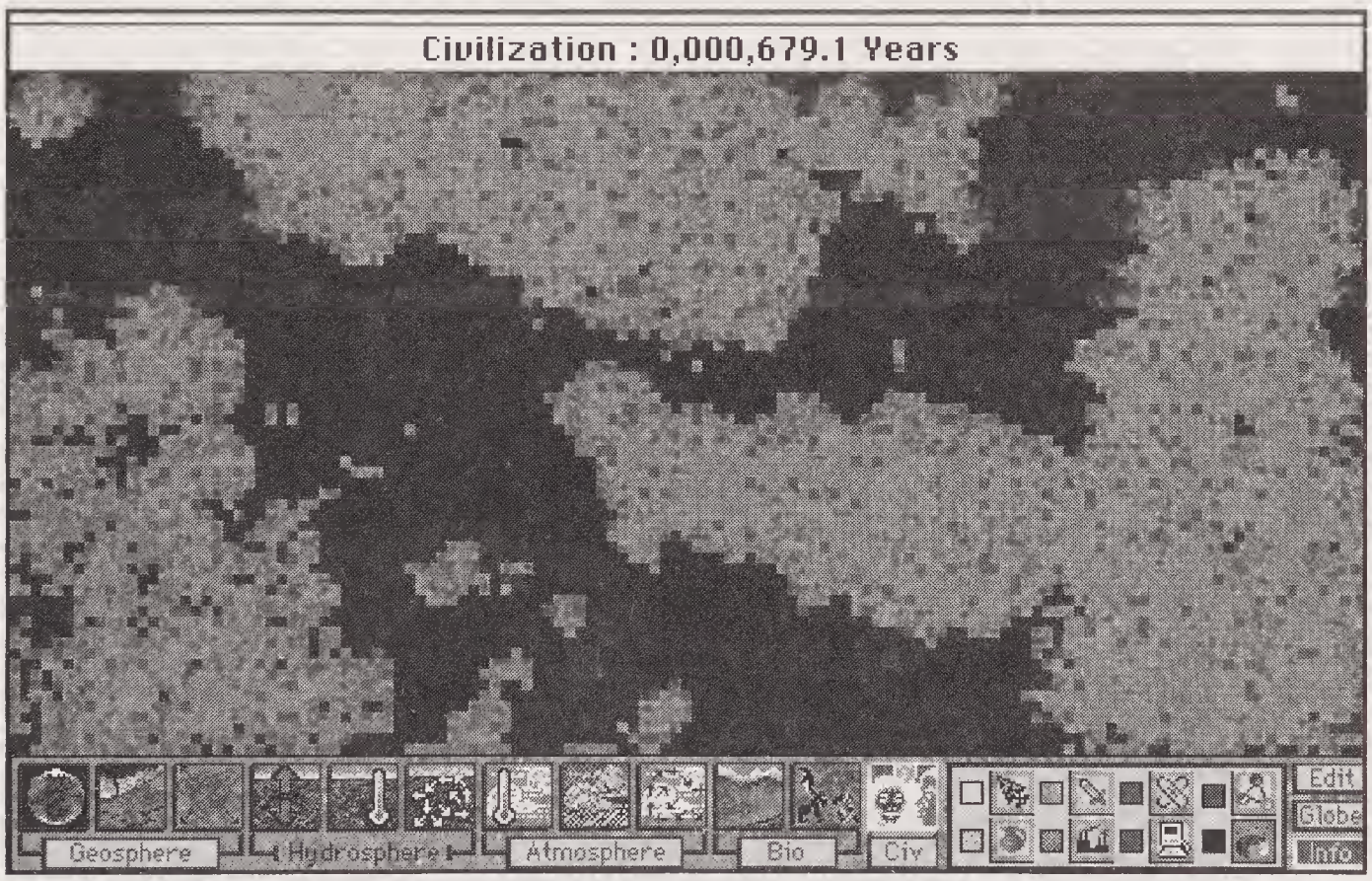
28. Wait until you have enough EU and place an Iron Age city.

29. As soon as you have enough energy, raise Hydro/Geo to the max.

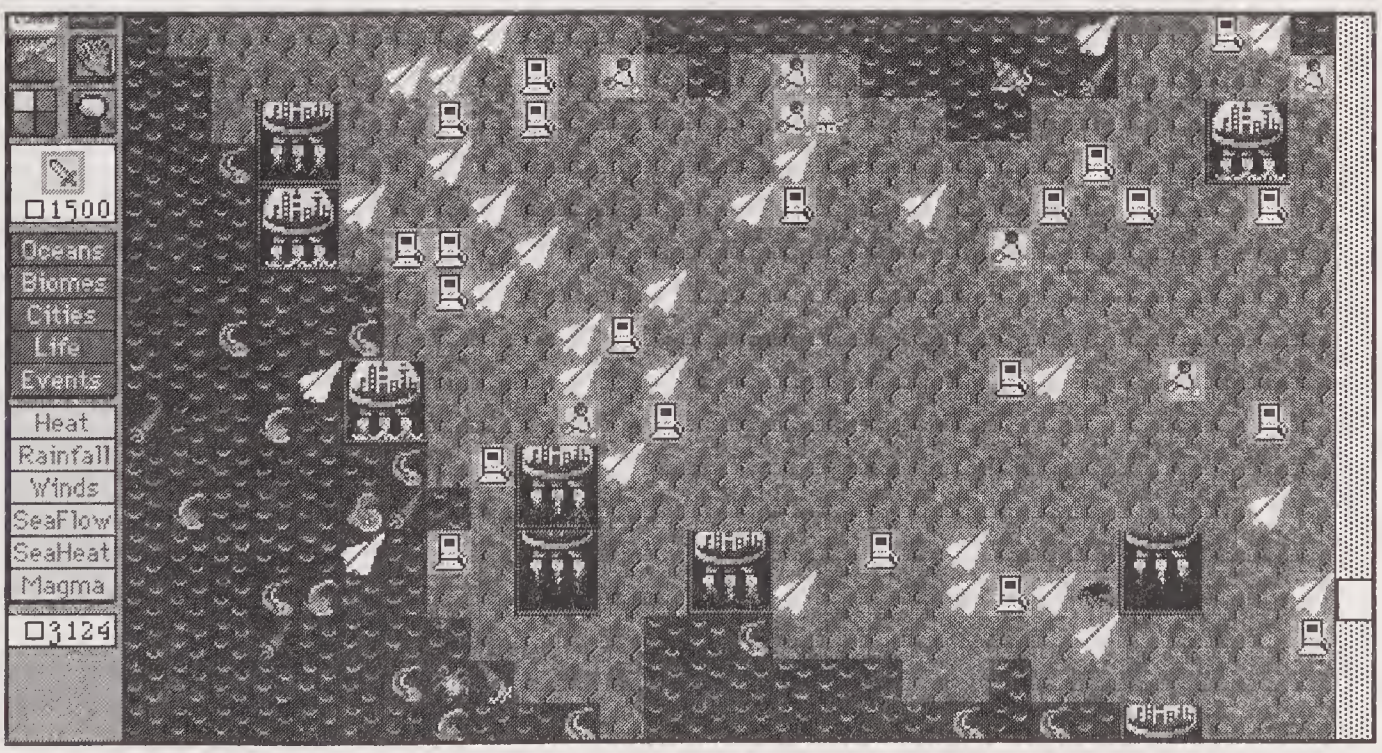
30. **Now raise Solar/Wind.**

31. **Finally, increase Science a few notches, but not necessarily to the maximum setting. Optionally, lower settings for Philosophy and Art/Media.**

Now wait. That's all it should take. Eventually, your people will evolve to the next technology, and before long they'll reach the goal population. From here on, you can keep



Venus at Exodus.



watching and they'll probably make it to Nanotech Age and eventually to Exodus. Don't forget, if they seem to be stuck at Nanotech and Info Age, but can't take off, give them some fossil and nuclear fuels to use and they'll probably take off very fast.

A Trick in Easy Mode

This only works in Easy mode, but if you want to have a lot of energy to work with, drop a Nanotech city on the surface of Venus right at the beginning of the terraforming simulation. Any other civilization would die in the blistering heat and poisonous atmosphere, but not the Nanotech folks. They can live just about anywhere. The advantage is that now, each cycle of the SimEarth clock gives you back eight energy units. Your energy will replenish so fast that you can proceed with the rest of the terraforming task with virtually no energy limits.

The "Turtle-Back" fractured dome.

Venus—The Hard Mode

Before trying Venus in the Hard mode, try it in the Easy or in the Experimental mode to find out basically what works. Run through the previous section to understand the basics of Venus.

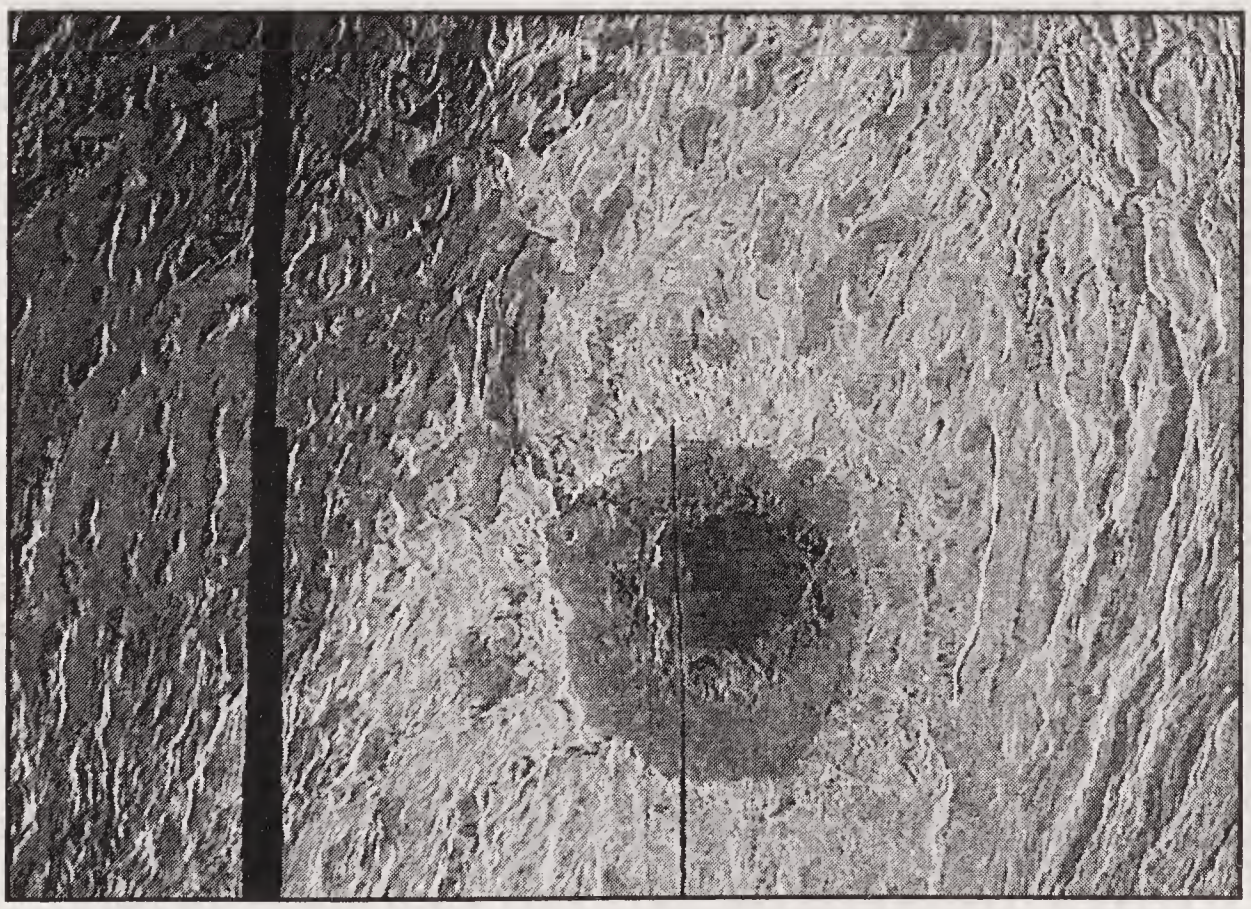
Terraforming Venus in the Hard mode is very difficult to describe. That's because you never really know how the model control panels will be randomized. If Erosion is high, for instance, it will be harder to get rid of carbon dioxide. If the greenhouse effect is low, you may have an easier time lowering the temperature. Many of the model controls can affect the way Venus will behave. The first thing to do is examine the model controls and see how they're set. That will give you some idea what you're up against. Of course, if you really don't like the odds, you can stop this game and start a new Venus simulation in Hard mode. The settings will be different each time.

Once you've checked out the model controls, you'll probably want to place four Oxygenators. Then, because you're out of energy units, you'll have to wait. It may take so long for the carbon dioxide to leave the atmosphere that you'll have regained a lot of energy units. If so, place another one or two Oxygenators. It will speed things up.

To further speed up the process, bring the Air Sample graph to the front, making it the active window, then turn off Update Background from the Option menu. That will cause time to pass much faster, but you won't see what's going on in the other windows. Once the carbon dioxide levels fall below 1%, turn Update Background on again. The air temperature should begin to fall soon, around .6% depending on the model settings.

Western part of Clotho Tessera, 300 km wide.

The Cleopatra impact crater.



Sinuous volcanic channel of the North Freyja Montes.

After the air temperature finally falls (and this could take quite a while), you'll want to drop an ice meteor, carve out oceans with the Set Altitude tool, place an N_2 Generator, one or two Vaporators, and a Biome Factory. For guidelines on performing these tasks, see the steps in the Easy mode. In fact, from here on, you'll probably do just about the same things as you would have when playing the Easy game.

Finally, you'll set down the best civilization you can (the best you can afford is Industrial Age) and set the Civilization controls to the maximum Agriculture. It may take a while to build up enough energy units to place the civilization, but while you're getting more EU, the biomes should be spreading across the surface of the planet.

Don't worry if there are some wild swings in oxygen. As the biomes grow, they'll burn frequently to get rid of the excess oxygen. Eventually you'll probably want to place prokaryotes in the oceans and destroy the Oxygenators. Even if there are wild swings in the oxygen levels, it seems that life won't be unduly affected by them. So proceed according to plan and get your people moving.

Maxwell Montes and Lakshmi Planum.

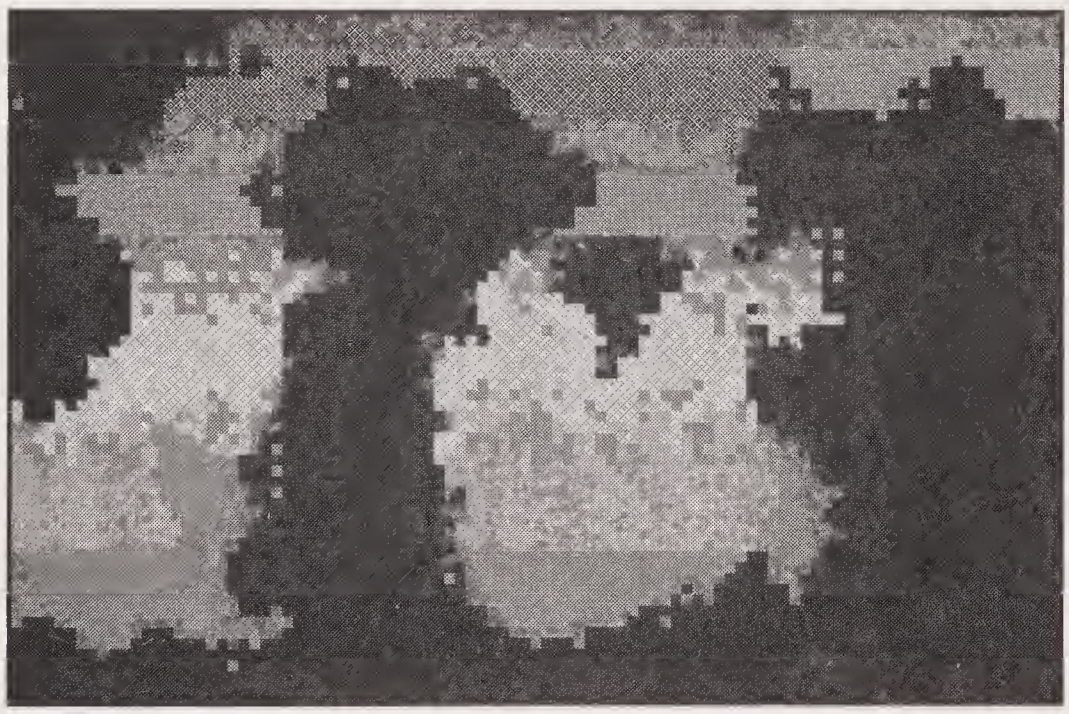
We usually wait until we have enough energy to place an Iron Age city. Then, as the energy units recharge quickly, we adjust the Civilization model settings until they are best for the advancement of the civilization. From there on, it's just a matter of waiting while the people spread across the land. Before long, your job is done and Venus is terraformed.

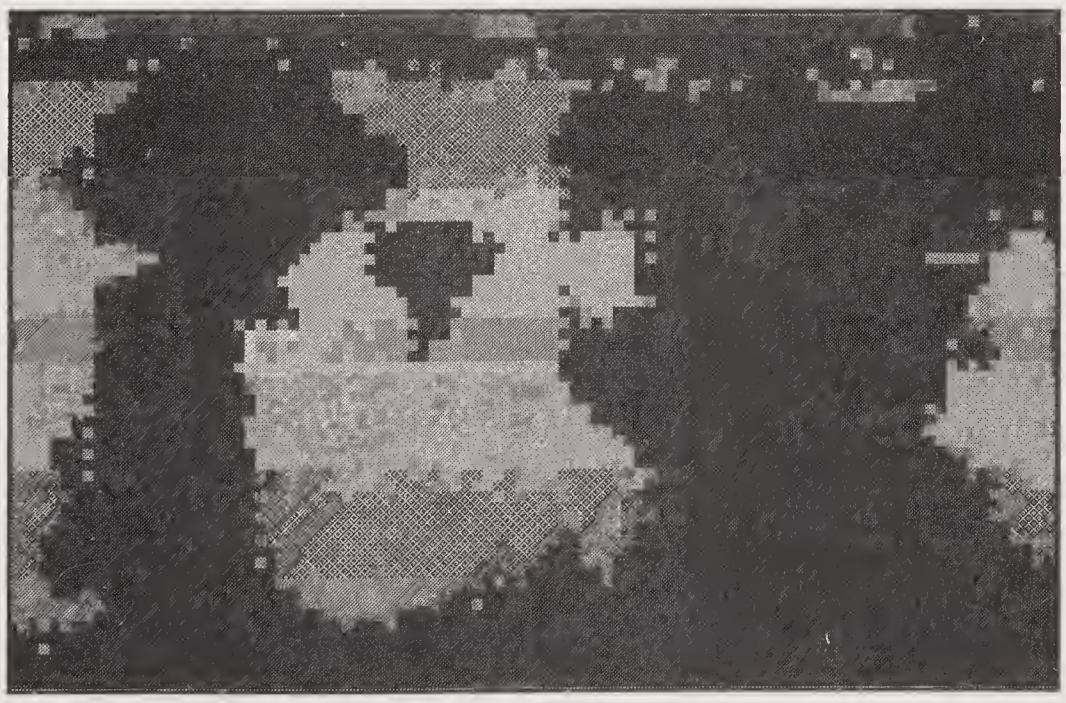
DAISYWORLD

DaisyWorld is based on James Lovelock's theoretical model that illustrates the Gaia principle in action. The scenario is well explained in the SimEarth manual. In Easy mode or any mode other than the Hard mode, about the only things you can do are play with Solar Input on the Atmosphere Model Control Panel, or place different animals on the surface and see what they do.

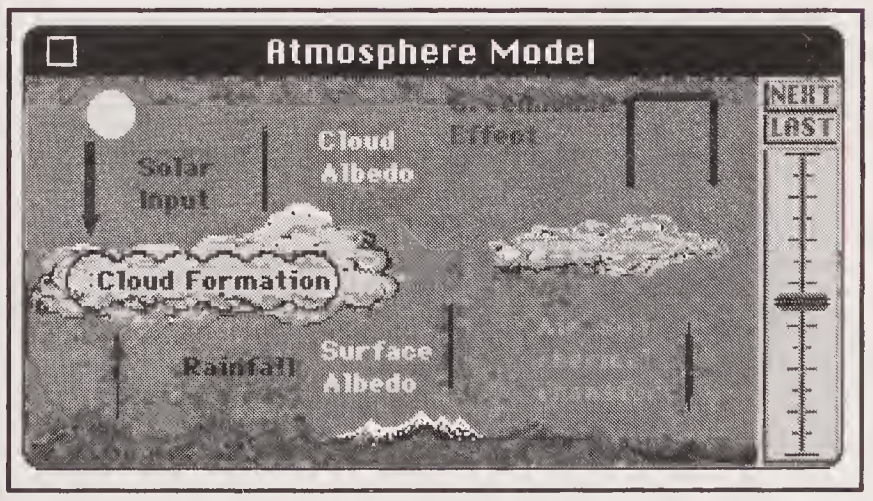
If you play DaisyWorld in the Hard mode, your job is much tougher. You'll have to place the daisies. They won't grow by themselves. And if you place a daisy in an area it doesn't like, it'll die. So, with a limited energy budget, you'll have to experiment carefully and find just the right daisy for the temperature in every location.

The best way to approach DaisyWorld in the Hard mode is to place a daisy and wait to see if it dies or





Watch what happens when you turn Solar Input lower. The daisies will get darker to absorb more heat. The opposite happens when you turn up the Solar Input.

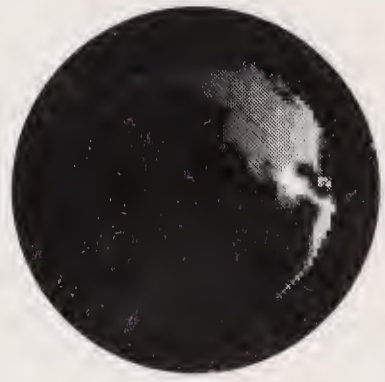


reproduces. If it dies, try another type of daisy. Of course, you want low albedo daisies (dark ones) in colder places like the poles and high on mountains. High albedo daisies go in the lowlands near the equator. You'll have to guess which ones to place, but at least you'll have some idea if you use common sense.

Another trick is to watch the daisies that do grow. Where do they stop? At the borders of their range, place the next daisy in order. For instance, if you have some very dark daisies at the poles and they spread out, but then stop, place some daisies one shade lighter at the point at which the dark ones stop. In this way, you can slowly work your way down (or up) moving from one "daisy zone" to another.

Part IV

Appendices



Try flipping the pages and watch the spinning globe in the right-hand corners of the next few pages. Just for fun...

Appendix A

Trouble Shooting SimEarth (SimEarth Field Manual)

Sometimes you just don't know what to do or who to call. If you find yourself in a situation you don't understand, try looking in this appendix. We've tried to answer the most commonly asked questions about SimEarth. Read the description of the situation, and if it seems to apply to you, read the answer. Couldn't be simpler.

IN THE GEOLOGIC TIME SCALE

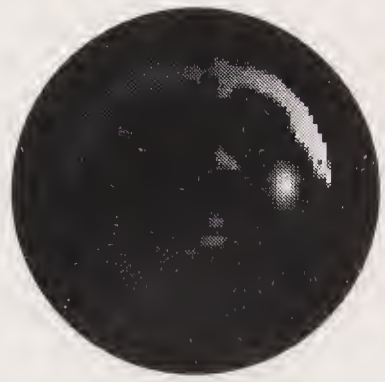
There's water on my new planet, but no message that oceans have formed.

Sometimes, especially if you're busy moving things around, it seems that SimEarth "forgets" to put the oceans formed message on screen. But if you see water on your planet, then you have oceans, even if they are very small ones.

There's not enough land on my planet.

There are several ways to build new land on a planet.

1. Use the Event Trigger to set off volcanoes.
2. Turn up the Volcano setting on the Geosphere Model Control Panel.
3. You might also consider turning up Core Heat and Continental Drift, and turning down Core Formation and Erosion. These settings will get you the maximum



continental drift. Turning down Erosion will allow your land masses to remain longer before natural forces break them down.

4. Use earthquakes to change the direction of magma flow, causing different plates to push land up as they bump into each other.
5. Lower the ocean level. You can do this by making the ice caps grow (a colder planet) or, on the Macintosh, by using the Secret Raise/Lower Oceans Trick mentioned in the Reference section.
6. Of course, you can use the Altitude Tool and simply build new land, which is the easiest and least creative way.

There's too much land on my planet.

Yes, you can get rid of unwanted land.

1. One way is to drop meteors on it. Meteors can carve a good chunk of land away.
2. Turn up Erosion. This will make your land erode away. As a byproduct, you should end up with a planet that has a lot of continental shelf area because the land erodes into the sea.
3. Raise the ocean level (make ice caps melt), or use the secret Raise/Lower Oceans Trick on the Macintosh.
4. Use the Set Altitude tool to lower excess land, if you can't think of anything better to do.

I can't get life to form on its own.

Sometimes life doesn't evolve spontaneously. If you've waited until, say 1.5 billion years and you still don't even have a prokaryote around, then you've got what I think of as a "dud" planet. It's probably best to start over, or just drop a prokaryote in the ocean and pretend it happened on its own.

When do prokaryotes normally evolve? Eukaryotes?

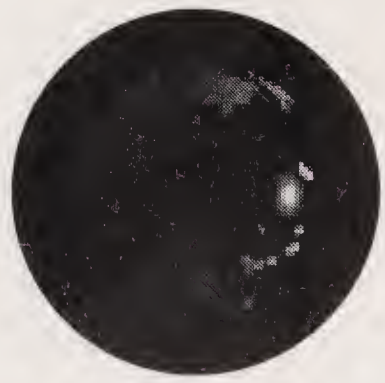
There is no normal time in SimEarth. If you want to see the average times for things, copy the chart on page 221 and run SimEarth several times, filling in the blanks. After five or ten runs, you'll have a pretty good idea when things usually happen. However, planets will keep their surprises. You never know for sure what will happen each time you play.

EVOLUTIONARY TIME SCALE

There's not enough land on my planet.

There are several ways to build new land on a planet. However, in this time scale, where time passes more slowly (only 750,000 years per cycle), some actions won't produce results as fast or as well as they did in the Geologic Time Scale.

1. Use the Event Trigger to set off volcanoes.
2. Turn up the Volcano setting on the Geosphere Model Control Panel.
3. You might also consider turning up Core Heat and Continental Drift, and turning down Core Formation and Erosion. These settings will get you the maximum continental drift. Turning down Erosion will allow your land masses to remain longer before natural forces break them down.
4. Use earthquakes to change the direction of magma flow to cause different plates to push land up as they bump into each other.
5. Lower the ocean level. You can do this by making the ice caps grow (a colder planet) or, on the Macintosh, by using the Secret Raise/Lower Oceans Trick mentioned in the Reference section.
6. Of course, you can use the Altitude Tool and simply build new land, which is the easiest and least creative way.



There's too much land on my planet.

There are several ways to destroy land on a planet. However, in this time scale, where time passes more slowly (only 750,000 years per cycle), some actions won't produce results as fast or as well as they did in the Geologic Time Scale.

1. One way is to drop meteors on it. Meteors can carve a good chunk of land away.
2. Turn up Erosion. This will make your land erode away. As a byproduct, you should end up with a planet that has a lot of continental shelf area because the land erodes into the sea.
3. Raise the ocean level (make ice caps melt), or use the secret Raise/Lower Oceans Trick on the Macintosh.
4. Use the Set Altitude tool to lower excess land, if you can't think of anything better to do.

The carbon dioxide level is dropping.

If the carbon dioxide level begins to drop, your planet will cool down. There are many ways of dealing with this situation. One is to wait and do nothing. Though your planet may experience an ice age, eventually the temperature will reach a steady state. And ice ages don't seem to inhibit evolution particularly. So you should be able to leave the situation alone.

If you really want to do something about the falling carbon dioxide level, here are some things you can do:

1. To get more carbon dioxide in the air, lower the CO_2 Absorption setting on the Biosphere Model Control Panel. Be careful when you do this. If you lower this setting too much for too long, you may find that oxygen levels begin to drop. After all, if the plants on the planet aren't absorbing carbon dioxide, they aren't going to give off as much oxygen either. If your oxygen levels drop too low, many of your life forms may die in mass

extinctions. Keep watching the Atmospheric Composition Graph or the History Graph to make sure this doesn't happen.

2. Use the Event Trigger to set off some volcanoes. This is particularly useful if your planet is short of land, but the effect on carbon dioxide is temporary.

3. To counter the fall in temperature, try raising the Greenhouse Effect on the Atmospheric Model Control Panel.

4. Likewise, you can use other settings on the Atmospheric Model Control panel. These include turning up Solar Input, turning down Cloud and Surface Albedo, and turning down Rainfall (which means less cloud cover).

The most effective combination, other than simply manipulating the Solar Input setting, is to use a combination of CO_2 Absorption and Greenhouse Effect as we have done in the Tutorial section of this book.

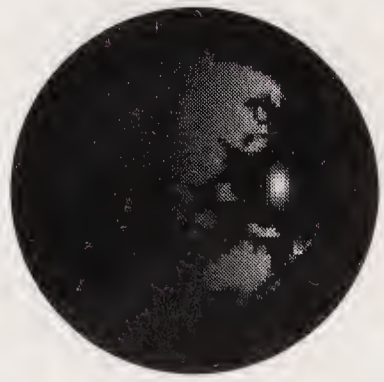
The carbon dioxide level is rising.

As carbon dioxide levels rise, your planet will heat up due to the greenhouse effect. If the planet gets too hot, life will die in mass extinctions and your oceans will boil off. This is a bad way to manage a planet.

1. To remove carbon dioxide from the air, raise the CO_2 Absorption setting on the Biosphere Model Control Panel. Watch out that you don't overdo it, though. If you take too much carbon dioxide out of the atmosphere, your planet will cool off, and could enter an ice age or start a cycle of wild temperature oscillations.

2. To counter the rise in temperature, try lowering the Greenhouse Effect on the Atmospheric Model Control Panel.

3. Likewise, you can use other settings on the Atmospheric Model Control panel. These include turning down Solar Input, turning



up Cloud and Surface Albedo, and turning up Rainfall (which means more cloud cover).

The most effective combination other than simply manipulating the Solar Input setting, is to use a combination of CO_2 Absorption and Greenhouse Effect as we have done in the Tutorial section of this book.

The carbon dioxide level is unstable.

Sometimes the whole planetary thermostat seems to go wacky and you'll see wild oscillations happening in the History window graph. These will sometimes even out by themselves, but you may not want to wait the millions of years it takes. The only way to counter these oscillations is to use a combination of the solutions offered in the previous two sections on rising and falling carbon dioxide levels. Try to time your intervention so that it catches the cycle with an opposing effect. If your timing is good, the swings should start to even out, eventually reaching a steady state.

The air temperature is dropping.

If the air temperature is falling, see the answers in the section on falling carbon dioxide.

The air temperature is rising.

If air temperature is rising, see the answers in the section on rising carbon dioxide.

The air temperature is unstable.

If the air temperature is unstable, see the answers in the section on unstable carbon dioxide levels.

I get the message, ALERT: Numerous Hurricanes threaten coastal areas.

Hurricanes usually occur in hot weather, so the chances are your planet's temperature is high. On the other hand, hurricanes aren't really very dangerous on the planetary scale, so you may not need to take any action. If you do want

to stop the hurricanes, the best bet is to lower the air temperature.

I get the message, WARNING: Planet Overheating.

Well, you're in trouble, aren't you? Better do something. Maybe read the section on rising carbon dioxide levels.

I get the message "Oceans are boiling off..."

You're fried. Or at least your planet is. Try to lower the air temperature, but usually, by the time you get this message, it's too late. Still that's your only hope. You could drop some ice meteors, too. Who knows? It might cool things off. It could happen. But it probably won't.

CIVILIZATION AND TECHNOLOGY TIME SCALES

The carbon dioxide level is dropping.

See the same question in the Evolution Time Scale.

The carbon dioxide level is rising.

See the same question in the Evolution Time Scale.

The carbon dioxide level is unstable.

See the same question in the Evolution Time Scale.

The air temperature is dropping.

See the same question in the Evolution Time Scale.

The air temperature is rising.

See the same question in the Evolution Time Scale.

The air temperature is unstable.

See the same question in the Evolution Time Scale.

There's not enough land on my planet.

Your options are much reduced in this time scale. You can use the Set Altitude Tool of course, to create new land, or you can set off some volcanoes. However, the geologic settings won't help you at the rate this time scale moves. One option is to kill off your civilization and build land with geologic forces before they can become civilized again. However, once your dominant life form is ready to become sentient, they're hard to stop. You can use the eradicate species option*, however, to get rid of the intelligent creatures. Then you'll have time to work before someone else gets smart.

* Hold down the Control key (Option on the Mac) and then select a life form as if you were going to place it on the map.

There's too much land on my planet.

The best way to get rid of excess land is to drop meteors on it. It's too late to use geologic solutions like turning up the Erosion setting. And of course it's never too late to use the Set Altitude tool.

I get the message, ALERT: Life Quality HELLISH! Arts/Media needs Energy.

If you're going to listen to the complaining of those lazy Sims, it's up to you. But if they're going to get ahead and reach the stars, they'll just have to rough it for a few thousand years. Or, you can be nice and let them have a nice Art/Media budget. They might make it anyway.

I get the message, ALERT: Advancement Slow. Science needs Energy.

Science is the most important factor in determining whether your Sims will reach the next level of technological development. If you get this message, it might mean that they are feeling a little stuck on a problem, and you need to send them an Einstein to figure it out. In other words, turn up the Science setting on the Civilization Model Control Panel.

I get the message, DANGER: Continual Warfare. Philosophy needs Energy.

If your Sims are using fossil fuels, they'll squabble over them, since they are a scarce resource and such fuels will tend to run out. When their squabbling gets out of hand, you get a world war. First, check the Philosophy setting in the Civilization Model Control Panel. If it is very low, try turning it up. The best way to stop the war, however, is to lower Fossil Fuels on the Civilization Model Control Panel as far down as you can.

I get the message, DANGER: Nuclear Detonations! Reduce atomic usage.

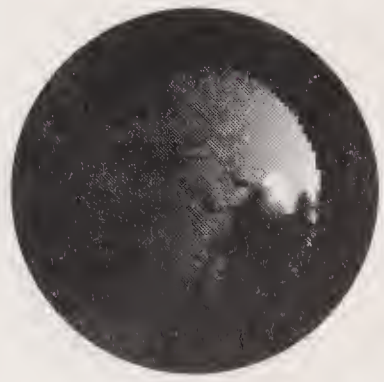
The boys are fighting over the radioactive resources. Instead of sharing like good little Sims, they're making bombs and hurling them at each other. The end result is a lot of trashed, radioactive zones and possibly a nuclear winter in which they'll all suffer and die. How do you help them? First, check the Philosophy setting in the Civilization Model Control Panel. If it is very low, try turning it up. On the other hand, for a sure cure with or without a very philosophical society, turn off (or at least turn way down) the Nuclear option in the Civilization Model Control Panel.

I get the message, ALERT: Fossil fuels are running out!

That's pretty obvious. Use less of that old black gold, or stop using it altogether. It's so obvious that I wouldn't expect anyone to look here for an answer. On the other hand, if it's so obvious, how come we keep on using them like there was no tomorrow? Don't answer.

I get the message, ALERT: Atomic fuels are running out!

See the answer to the previous situation.



I get the message, "Numerous Hurricanes threaten the coasts."

Hurricanes usually occur in hot weather, so the chances are your planet's temperature is high. On the other hand,

hurricanes aren't really very dangerous on the planetary scale, so you may not need to take any action. If you do want to stop the hurricanes, the best bet is to lower the air temperature.

I get the message, WARNING: Planet Overheating.

Well, you're in trouble, aren't you? Better do something. Maybe read the section on rising carbon dioxide levels in the section on the Evolutionary Time Scale.

I get the message "Oceans are boiling off..."

You're fried. Or at least your planet is. Try to lower the air temperature, but usually, by the time you get this message, it's too late.

I can't get Stone Age to survive.

Stone Age civilizations are the most fragile of all those in SimEarth. Especially at the beginning, they can be wiped out by a single plague or tribal war. Or they might not be living in a very good place for them. If the biomes around them are unfriendly to their species, they won't thrive there. Even if they do manage to build cities on such biomes, they won't be very large cities.

The two things you can do are:

1) Make sure your Sims' cities are in an area that's most suitable for them. If necessary, move them, or move some of their travelling populations.

2) Turn up the Agriculture setting in the Civilization Model Control Panel. This will give your people a good chance to succeed since they will keep their population growing even under adverse conditions, and they'll send out more explorers who will seek new territories. Once they have spread out to ten or twenty cities, they should be fairly safe unless you do something to destabilize the situation.

Also, be sure the Science setting is high enough so they can advance to the Bronze Age when they have become stable, and make sure they are using all the available energy sources at their disposal.

I can't get my civilization to Nanotech.

Sometimes the Sims are doing just fine, but they can't quite make it to that elusive new technological level. The main ingredients of successful advancement are lots of Sims (high population) and lots of energy devoted to Science. If your population is already at the Info Age, then they can spread out over the surface of the planet in a thundering horde of jets. So the only limitation may be available space to settle. By now, you should be able to turn down the Agriculture setting on the Civilization Model Control Panel, but don't turn it off. Keep Science high, and also turn up Medicine. Turn Arts/Media nearly off. It has no effect on your Sims other than to make them grumpy.

Make sure you're using all the "clean" energy resources. Unless you're really land poor, you should be able to do without both fossil fuels and nuclear power. Once again, if your Sims don't have enough land, make some. If your population is high enough, you're generating enough work, and your Science setting is high enough, nothing can stop the Sims.

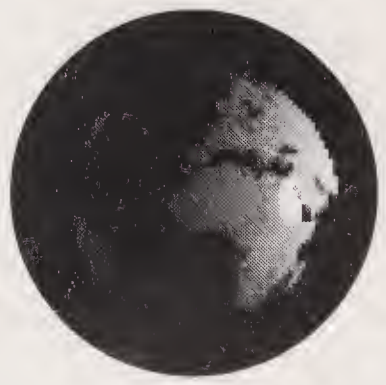
I can't get my civilization to Exodus.

Reaching the Exodus is not too hard, but sometimes, for a variety of reasons, your Sims may get stuck just before that point. They've reached the Nanotech Age, but they can't seem to get to terminal velocity and take off.

First, check the Science setting in the Civilization Model Control Panel. It must be fairly high. To reach Exodus, there must be a fair number of Nanotech cities, and the Science setting determines how many of them will appear.

The other factor is the amount of energy produced. Read the section previous to this one, about reaching the Nanotech Age. The information there applies here, too.

At this point, when your Sims are obviously very close to lift-off, you can give them a little turbo charge. If you've refrained from using up your fossil fuels and nuclear materials, you can boost these two energy sources up in the



Civilization Model Control Panel. Within a few more cycles of the game, your Sims should achieve the necessary levels to take off. I usually look to be producing more than 30,000 total work energy units before I boost the energy sources. I also look to have a total greater than 60,000 after boosting the energy, and I keep the Science setting high and the others (except Medicine) fairly low.

MARS

I can't get the temperature up.

Use CO_2 Generators to create a little greenhouse effect.

I can't get the oceans to form.

Use one or more ice meteors, then use the Set Altitude tool to dig a big trench. The water will fill the trench. If the water freezes, don't worry about it. At least it's water.

I can't get biomes to grow.

Place a biome factory, then use the Mover tool to keep placing it in new positions once a biome has gotten started in its last location.

I've got biomes growing, but I don't seem to have enough biomass to reach the terraforming goal.

There are biomes and there are biomes. For instance, deserts create less biomass than grasslands do. However, for really hefty biomass, there's nothing like a forest. Boreal and ordinary forests will do. It's pretty hard to get Mars hot enough to support tropical rainforests.

The key to getting the right biomes is actually pretty simple. The more Vaporators you place on the planet, the wetter it will be. You'd be surprised at the difference just one more (or one less) Vaporator can make.

I've got biomes, but they keep disappearing, then reappearing.

You may have a very high oxygen level, or it may be fluctuating. What's happening is that fires are breaking out

over the surface of the planet, burning away the biomass, and at the same time removing oxygen from the atmosphere. I usually ignore it. It doesn't seem to stop my Sims from expanding, and eventually it usually evens out. Also, remember that once you finish terraforming your planet, you gain access to the rest of the model control panel settings. Then you can take action to control the oxygen content of the planet through the CO_2 Absorption level.

How do I know when I've been successful at terraforming?

The program will tell you when you've succeeded. Look at the Report window to see what your goal is and how close you are to achieving it.

VENUS

I can't get the temperature down.

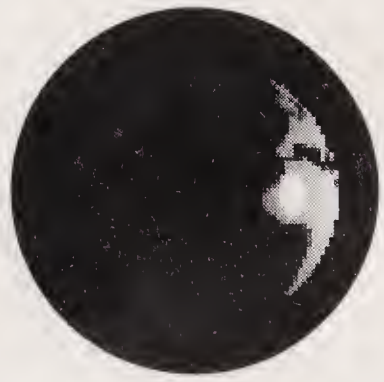
Use Oxygenators to replace the carbon dioxide. That's about all you can do at first. Then wait for the temperature to fall. Watch the History window carefully. Turn on CO_2 and Air Temp. Eventually, you'll see the CO_2 level start to fall dramatically, closely followed by the temperature. You may need to place anywhere from four to twelve Oxygenators, though. It mostly depends on how quickly you want results.

I can't get the oceans to form.

Wait until the air temperature has fallen about halfway down the History window graph. Then use one or more ice meteors. Finally, use the Set Altitude tool to dig a big trench. The water will fill the trench. You may be completely surprised to find that the water even freezes in places, despite readings from the Examine tool that your surface temperature is in excess of 200 degrees Centigrade. Don't trust that Examine window. It's a buggy sucker and lies to you for the fun of it. Well, anyway, use the History window, not the Examine window.

I can't get biomes to grow.

Place a biome factory, then use the Mover tool to keep placing it in new positions once a biome has gotten started in its last location.



I've got biomes growing, but I don't seem to have enough biomass to reach the terraforming goal.

There are biomes and there are biomes. For instance, deserts create less biomass than grasslands do. However, for really hefty biomass, there's nothing like a forest. Boreal and ordinary forests will do. If you can get it wet enough, you can grow tropical rainforests, the best biomass producers of all.

The key to getting the right biomes is actually pretty simple. The more Vaporators you place on the planet, the wetter it will be. You'd be surprised at the difference just one more (or one less) Vaporator can make.

I've got biomes, but they keep disappearing, then reappearing.

You may have a very high oxygen level, or it may be fluctuating. What's happening is that fires are breaking out over the surface of the planet, burying away the biomass, and at the same time removing oxygen from the atmosphere. I usually ignore it. It doesn't seem to stop my Sims from expanding, and eventually it usually evens out. Also, remember that once you finish terraforming your planet, you gain access to the rest of the model control panel settings. Then you can take action to control the oxygen content of the planet through the CO_2 Absorption level.

How do I know when I've been successful at terraforming?

The program will tell you when you've succeeded. Look at the Report window to see what your goal is and how close you are to achieving it.

HERE ARE ALL THE SIMEARTH MESSAGES:

ALERT: Numerous Hurricanes threaten coastal areas.

ALERT: Meteor Storm. Airborne dust threatens life.

WARNING: Planet Overheating.

WARNING: Mass Extinctions are occurring.

That is not allowed in this TimeScale.

WARNING : Nuclear winter detected.

ALERT: Atomic fuels are running out!

ALERT: Fossil fuels are running out!

ALERT: Sea Level is dropping as the icecaps grow.

ALERT: Sea Level is rising as the icecaps melt.

DANGER: Nuclear Detonations! Reduce atomic usage.

DANGER: Widespread Plague. Medicine needs Energy.

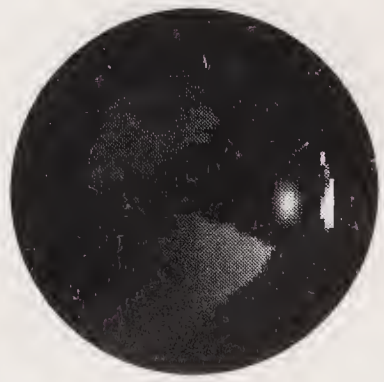
DANGER: Continual Warfare. Philosophy needs Energy.

ALERT: Advancement Slow. Science needs Energy.

ALERT: Life Quality HELLISH! Arts/Media needs Energy.

ALERT: Birth Rate Low. Agricultural needs Energy.

WARNING: Severe pollution problem.



Life Quality Ratings in SimEarth

Hellish

Miserable

Bad

Unpleasant

Tolerable

Pleasant

Good

Marvelous

Heavenly

Appendix B

Stupid SimEarth Tricks

Not everything in SimEarth is obvious. There are several tricks, both intentionally added and unintentional, that make the game more fun. A few of these tricks are very useful. Others are, well, pretty useless.

Not all these tricks work on all versions of the program. In fact, as of the time of this writing, we've discovered only a few tricks that work on the IBM version. The rest work on the Macintosh only.

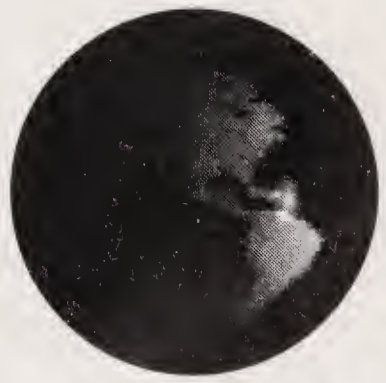
THINGS YOU CAN TYPE:

On all versions...

Slowly type J O K E to get a little SimHumor.

The Secret Life Form

There is a life form that does not appear in the SimEarth manual or in the Place Life palette. No, I don't mean carniferns. This life form is cooked up using a fairly high-tech recipe. Take a Nanotech city (or 3) and liberally apply radioactive material. The results should be amusing. Be sure to click on the LIFE button in the Edit window to see what emerges.



On the Macintosh only (so far)...

Slowly type F U N D for SimHumor, SimCity style.

Slowly type S M O O to turn your planet into a sort of billiard ball. It makes all your surface the same altitude.

Slowly type R A N D to turn your planet's surface into a jumble of rock. What it does is randomize the surface of the planet. Can be interesting to see what it does from there, especially in the Geologic Time Scale.

Slowly type E R A D to destroy all life on the planet. Remember, there is no undo key. If you type this, all life, including all biomes, will be eradicated.

Raise/Lower Oceans Trick

We've already mentioned this trick, but we'll repeat ourselves. Simply hold down the Option key and then click and hold on the Raise/Lower Land icon in the Edit window control panel. A small slider bar should appear to the left of the icon. Now, without releasing the mouse button, move up or down. Your oceans will rise or fall depending on the direction you move the mouse. Be careful, though. You could easily flood your world and kill all land life, or you could dry it up and kill everything. Also, in our experience, there's a slight chance that the computer will bomb when using this trick, so don't do it on a planet you haven't saved unless you don't care.

Ice Meteor Trick

One of the unintentional tricks we discovered is the Ice Meteor Trick. To raise your ocean levels, simply select the Ice Meteor from the Place Life palette, but don't use it. Just selecting it should raise the ocean level. This is particularly useful in the terraforming scenarios to save on actually dropping ice meteors.

In the very improbable department...

We've found some odd behavior in SimEarth. For instance, have you ever tried putting a fish on land? If you put it on a biome, it will die. But try putting it on a "no biome." It will sit there until a biome comes along. More than that... If you can get fish to intelligence (which is one of the harder things to do

in SimEarth unless you use the monolith), you'll find that fish cities live quite well on no biomes. Again, if a biome comes along, they have to pack up and leave.

This anomaly seems to work also with some other aquatic creatures. Try some experiments.

In the fatal department or

Bombs Away...

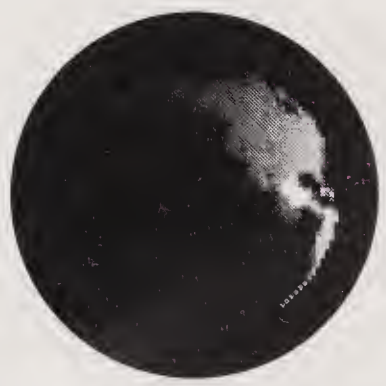
Various things are virtually guaranteed to bomb SimEarth. Here's one that always short-circuits the Macintosh version (and the Mac it's running on). What you do is raise the ocean level or lower the land level when civilization is present until there is no land left. Apparently you can't have civilization and no land at the same time. You get a bomb and a "divide by zero" error.

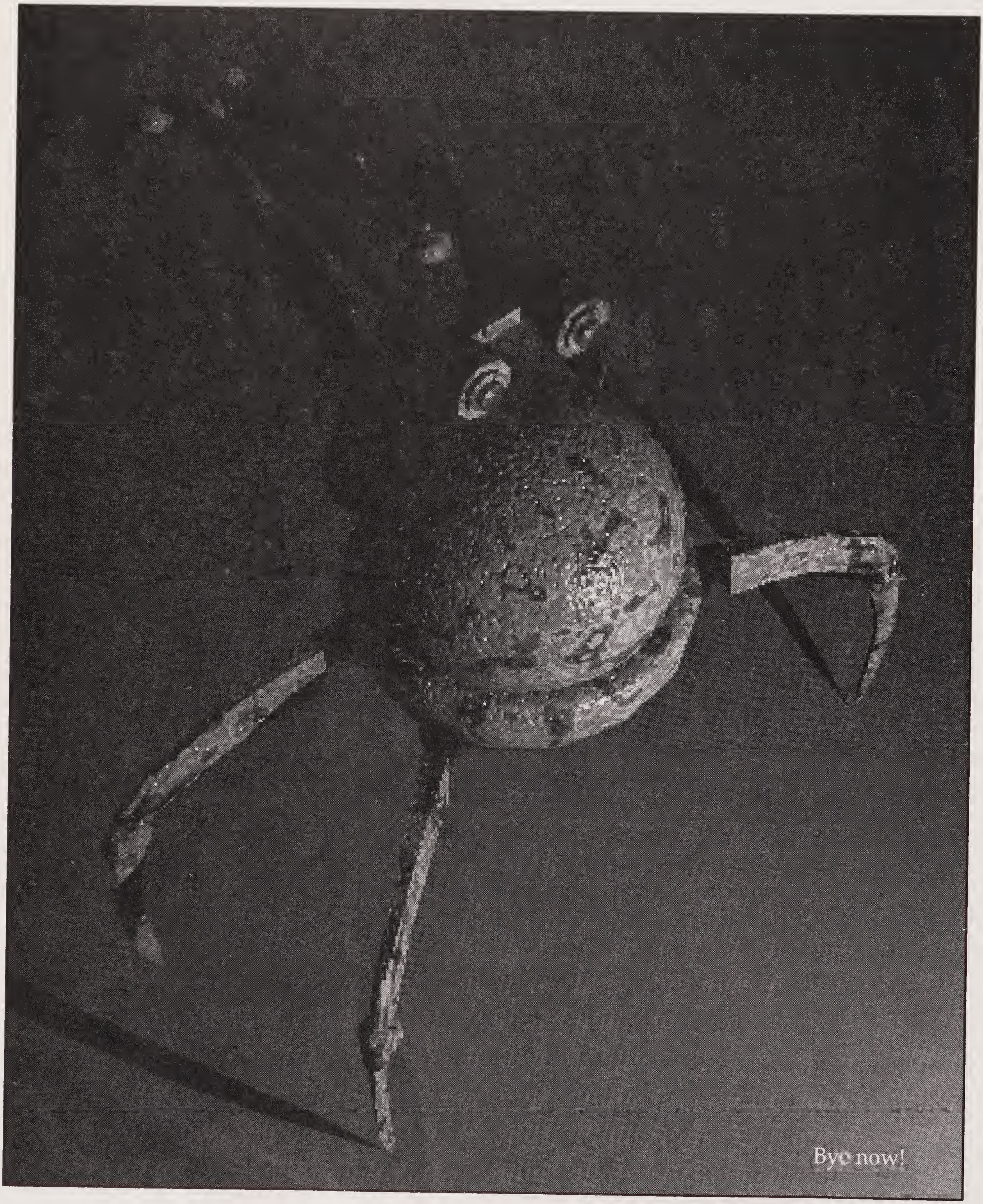
In the "What's this for?" department...

If you hold down the Shift and Control keys (IBM) or the Shift and Option keys (Macintosh) and then click anywhere in the display area of the Edit window, you'll create what is called a "SiteData" file on your current disk drive. This file currently has no use, though Maxis says it may be used in a "future product." Our best guess is that the site data may be used to create locations for SimCity 2 cities. But don't quote us.

On the Mac, you'll see a new icon called SimEarth–SiteData. On the IBM, you'll see a file called GAIA.SEC. Each time you create a new site data file, it replaces the old one. Just thought you'd like to know...

Mac SiteData icon.




Bye now!

Appendix C

Glossary

In this section is the same glossary that you will find in SimEarth by opening the Glossary window from the Windows menu. We've reprinted it here for convenience.

Aerobic- Requires oxygen. This can apply to animals, machines or processes.

Air Pressure- The pressure caused by air molecules bouncing against a surface. Vacuum has no air pressure.

Albedo- The reflectivity of a surface. A surface with high albedo will reflect sunlight. A surface with low albedo will absorb sunlight. Snow (high albedo) reflects sunlight and remains cold.

Anaerobic- Does not require oxygen. This can apply to animals, machines or processes.

Animal- An organism of the kingdom Animalia. Properties include the ability of locomotion and a nonphotosynthetic metabolism.

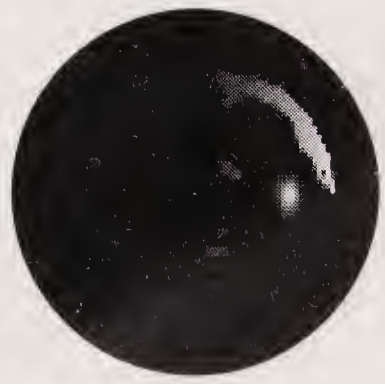
Arctic- Areas that are snow or ice covered. Cold and dry. See tundra.

Arthropod- The phylum of animals which includes insects, crustaceans, arachnids, and myriapods.

Atmosphere- The blanket of gasses which envelope a planet.

Atomic Age- This era is characterized by nuclear power, Aircraft, Radio, and Chemical Fertilizers.

Axis- The planetary center of rotation. On Earth, the axis is a line passing from the north pole to the south pole.



Biomass- The total dry weight of all living material on a planet.

Biome- A major ecosystem such as temperate grassland, tropical forest or desert.

Biome Factory- A SimEarth tool which produces the best biome for the environment it occupies.

Biosphere- The areas of a planet which are inhabited by life. On Earth this includes portions of the crust, hydrosphere, and atmosphere.

Bronze- An alloy of tin and copper that is stronger than either.

Bronze Age- This era is characterized by bronze tools, sail ships, clay tablets and irrigation.

Boreal- Also known as Boreal Forest. Biome inhabiting cool regions with airborne moisture. The trees are usually conifers.

Carbon Dioxide(CO_2)- A gas composed of two oxygen atoms and one carbon atom. This gas is used by plants in photosynthesis and produced by organisms as they respirate.

Carniferns- A SimEarth name for mobile, carnivorous plants. The Venus Flytrap is a carnifern.

Cetaceans- The order of mammals that is exclusively sea borne. This includes dolphins and whales.

CO2 Generator- A SimEarth tool that releases carbon dioxide into the atmosphere.

Class- The classification of life under Phylum. The major classes of Chordata are fish, amphibian, reptile, avian, and mammal. See order.

Cloud Albedo- The albedo of clouds. High cloud albedo can keep Earth cool. See albedo.

Conifer- Cone bearing trees and shrubs. This includes evergreens, pines and firs.

Continental Drift- The theory that continents have changed position on Earth. This is the predecessor to Plate Tectonics Theory.

Core- The extremely dense, fluid center of Earth. It is probably composed of molten iron. See mantle.

Crust- This thin outer shell of the Earth is only a few miles deep. See mantle.

Cryosphere- The frozen regions such as the icecaps, tundra, and mountain glaciers.

Desert- An ecosystem characterized by hot weather and little water.

Dust- In SimEarth, dust refers to airborne dust, ash and detritus. This can darken a planet, reducing photosynthesis and absorbing heat.

Ecosystem- A group of plant and animal species living together in rough balance.

Eukaryote- Single-cell microbes with a nucleus.

Evolution- The process by which life has changed and diversified.

Explosive Upwelling- Sometimes hot spots are very hot. This can lead to a Volcano that is a thousand times the size of any seen by man. These upwellings spew the material for continents and are possibly Nemesis.

Extinction- The elimination of a species.

Geosphere- See lithosphere.

Greenhouse Effect- Planetary heating induced by greenhouse gases.

Greenhouse Gases- Certain gases will let solar radiation enter the atmosphere but not leave. The most common of these are carbon dioxide, methane, and water vapor.

Hot Spot- Mantle material flows up and down as well as sideways. Hot magma sometimes rises from the core to the crust creating a Hot Spot. See volcano.

Hydrosphere- The water portions of Earth. This includes oceans, lakes, rivers, and clouds. SimEarth restricts the term to oceans.

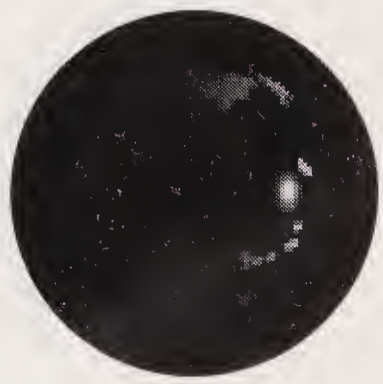
Industrial Age- This era is characterized by the use of fossil fuel engines, automobiles, telephones, and animal husbandry.

Information Age- This era is characterized by computers, global communications, robotic labor, and ecologic awareness.

Insolation- INcoming SOlar radiATION.

Iron Age- This era is characterized by iron tools, sextants, paper, printing press, and horse drawn plows.

Kingdom- The most general classification of life in Biology.



The five kingdoms are prokaryotae, protoctista(eukaryotes), fungi, plantae and animalia.

Jungle- Also known as Tropical Forest. This biome thrives in hot, wet climates.

Lava- This is the lighter materials of magma that comes to the surface via volcanos and upwellings.

Life Forms- A science fiction term for organisms.

Lithosphere- The rock portions of the planet: Plates, Crust, Moho, Mantle, and Core.

Magma- Molten rock found beneath the Earth's crust. See lava.

Mantle- The layer of magma between the crust and core of the Earth. This area is constantly flowing at a speed measured in centimeters per year.

Mass Extinctions - At various times in Earth's history large numbers of species have vanished. Records indicate that at each of these times between 5% and 50% of the species became extinct. See Nemesis.

Methane(CH_4)- A gas composed of one carbon atom and four hydrogen atoms. It is primarily produced by primitive microbes which currently live in the intestines of larger organisms.

Microbe- A single-celled organism.

Mollusk- Class of invertebrates that includes snails, mussels and octopuses.

Monolith- A SimEarth tool for advancing life. Taken from Arthur C. Clarke's "2001: A Space Odyssey".

Moho- Also called the Mohorovicic discontinuity. The turbulent region between the crust and the mantle.

Mutate- When an organism makes an inexact copy of itself. The variability which allows evolution to occur.

N_2 Generator- A SimEarth tool for introducing Nitrogen into the atmosphere.

Nanotech Age- This era is characterized by molecular construction, molecule sized machines, and completely automatic production.

Nemesis- The culprit in the periodic mass extinctions (every 25 million years or so). Identity unknown, the two prime suspects are Meteors(caused by a dark star orbiting our sun) and Explosive Upwellings.

Nitrogen(N_2)- A gas composed of two nitrogen atoms. It is a heavy, stable gas comprising 80% of Earth's atmosphere.

Order- The classification of life under Class. The major orders of mammal are rodents, felines, canines, ruminants, primates and cetaceans.

Organism- An independent unit of life. All plants, animals and microbes are organisms.

Oxygen(O_2)- A gas composed of two oxygen atoms. This is used by organisms when they respirate.

Oxygenator- A SimEarth tool that converts carbon dioxide to oxygen.

Photosynthesis- A process that uses light to create energy storing chemicals such as sugar. Oxygen is a by-product of photosynthesis.

Plant- An organism that uses photosynthesis to feed itself.

Plate Tectonics- Theory that the Earth's crust is formed of mobile plates sliding across the mantle. Even the ocean bottoms consist of plates.

Phylum- The classification of life under Kingdom. The major animal phylums are chordates, arthropods and invertebrates. See class.

Phytomass- The total dry weight of all plant material on a planet.

Planet- An astral body that orbits a star.

Planetesimal- A small planet. Small usually means moon-sized or less.

Prokaryote- Primitive single-cell microbes with no nucleus.

Radiate- The class of invertebrates including jellyfish and starfish.

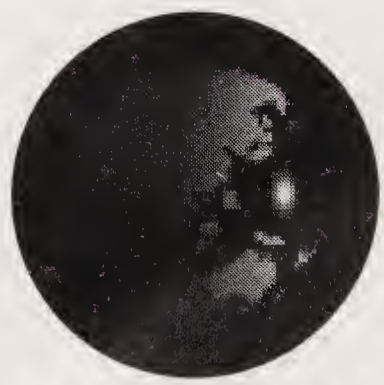
Sapient- An intelligent, tool-using organism.

Stone Age- This era is characterized by stone tools, domestication, fire, and cultivation.

Swamp- Also known as tropical grasslands. This biome is composed of plants and animals that thrive in slow shallow water and on muddy shorelines.

Terraform- The process of modifying an entire planet for a particular purpose.

Trichordate- A SimEarth term for an order of radiates with three radiating spines.



Tundra- This biome is characterized arctic conditions and year round cold weather.

Upwelling- When two plates pull apart, lava will flow up between them forming small rises like the Mid-Atlantic ridge. See Plate Tectonics.

Vaporator- A SimEarth tool that stimulates global plant growth by increasing humidity.

Volcano- When a Hot Spot is over a thin section of crust, a volcano can erupt. Volcanos spew lava and ash over an area often forming new cone-shaped mountains.

Water Vapor(H_20)- Water can be a gas with one oxygen atom and two hydrogen atoms.

Zoomass- The total dry weight of all animal material on a planet.

Bibliography

There are hundreds and hundreds of books and articles about our world. People have been writing about nature and science almost since they started writing. Therefore it is no real surprise that there is more available than any one person could read in a lifetime, let alone in a deadline. Therefore, I've had to limit my reading to a few books in which the authors had done a lot of the outside reading for me. These are the books I include here. I very strongly recommend each of them. They all cover the topics mentioned in this book in more detail, and they are all very entertaining as well.

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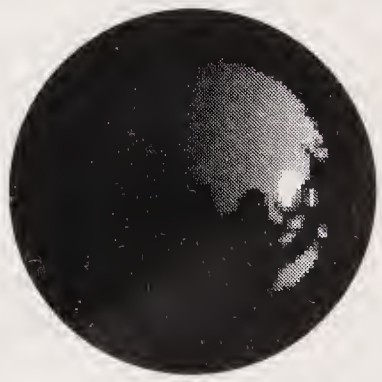

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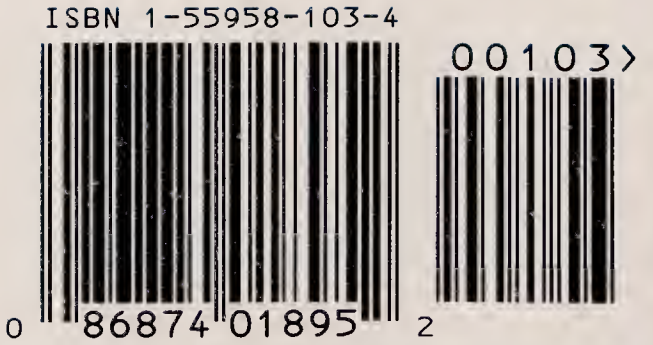
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